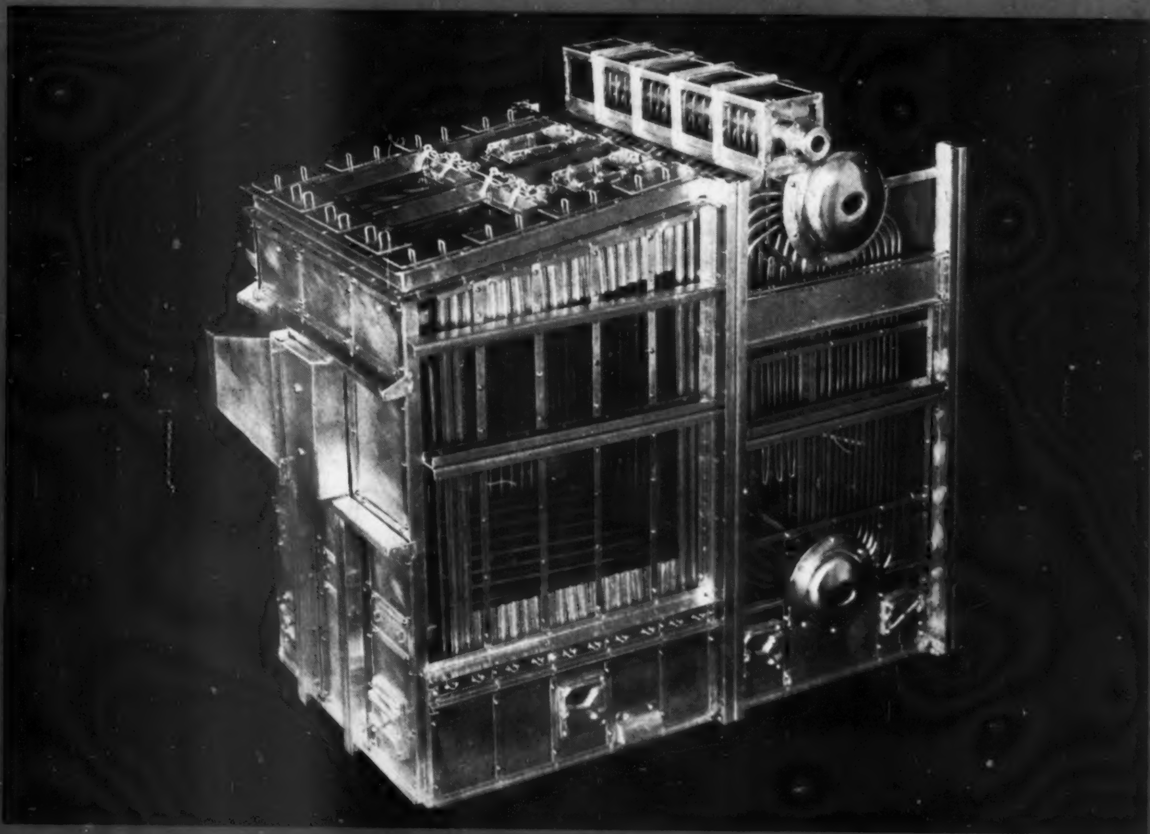
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 12, No. 12 JUNE, 1941 25c a copy



Model of two-drum steam-generating unit exhibited at Boiler Inspectors Meeting; see page 43

Application of Heat Insulation

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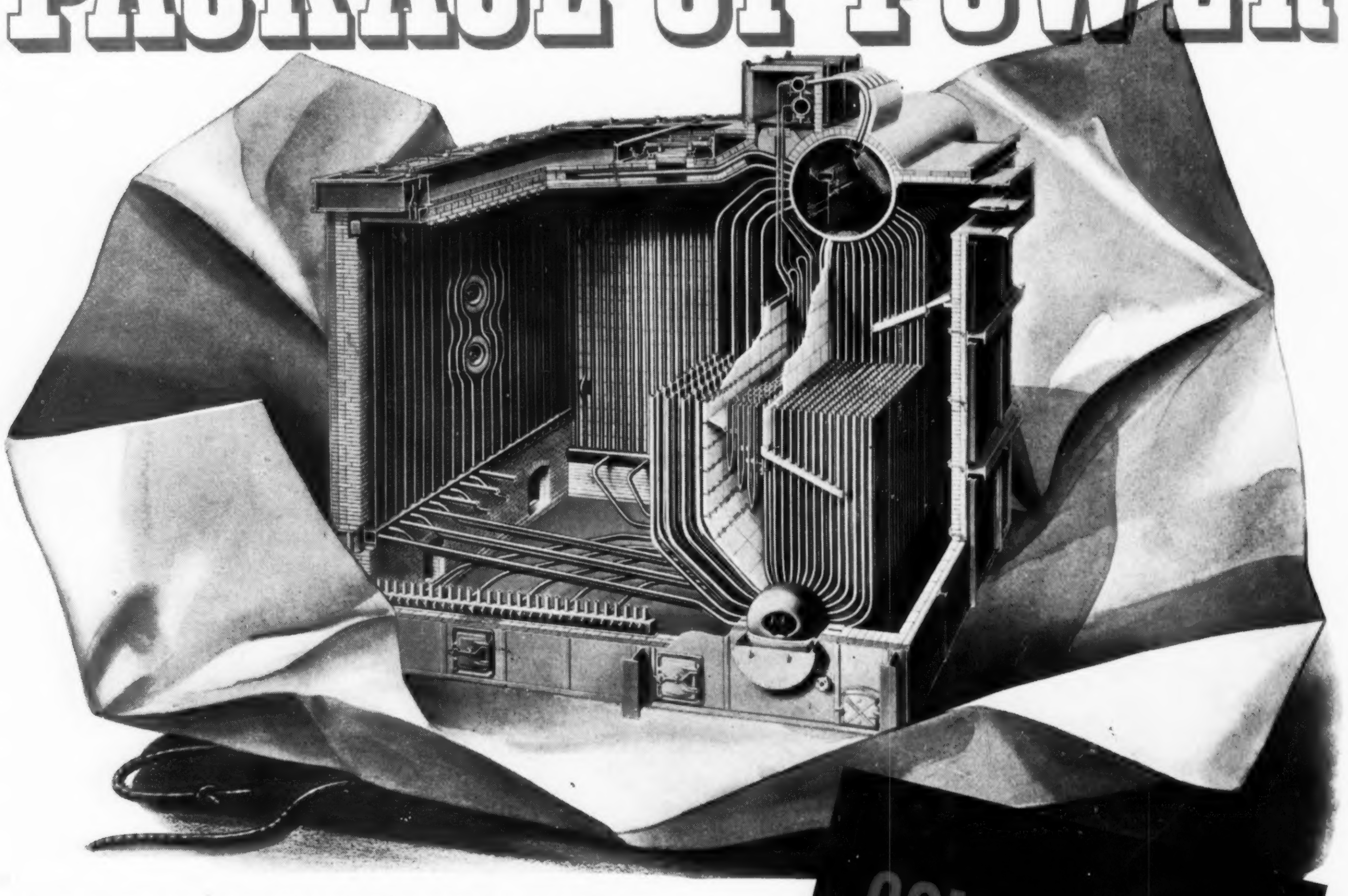

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWELVE NUMBER TWELVE

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FOR JUNE 1941

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Threatened Oil Shortage Creates Stoker Demand

The further diversion of tanker capacity by the Government for naval use and for supplying Great Britain has created a threatened shortage along the Atlantic Seaboard that is likely to become serious; for it will be many months before the projected pipe lines can be constructed. This situation has already resulted in a marked swing to stoker firing, not only as to new installations but also in many existing oil-burning plants which at this time cannot afford to risk a curtailment or stoppage in fuel supply. Larger units with furnaces equipped to burn either pulverized coal or oil are, of course, not affected as the changeover can be readily made.

The available oil supply at the source is reported as adequate to meet all present requirements; it is the transportation problem that has become acute. This at present affects only those sections of the country that are dependent upon water-borne oil; hence the Middle West, Southwest and Pacific Coast regions have not been affected.

With the appointment of Secretary Ickes as Oil Administrator it is likely that stringent conservation measures will be adopted and that all defense uses for oil will receive priority. Fortunately, the coal supply is ample in all the localities affected to meet anticipated demands.

Power for Defense

Regardless of the psychological effect of the President's recent proclamation of a full national emergency, it did not materially alter the power situation which had already been geared to the Government's accelerated production program for defense through close cooperation between the OPM, the Federal Power Commission and utility representatives.

There appears to be agreement among most of those in a position to know the facts that present capacity, new construction and scheduled extensions to utility systems, augmented by the very substantial additions now being made to private plants, should be able to keep pace with the increasing power demands during the remainder of this year and most of next. This may not apply to certain sections and isolated cases but such situations can usually be assisted through interconnection with adjacent territory.

Fortunately, large blocks of power for the bulk production of certain strategic materials, such as aluminum, will be available from some of the federal hydro developments now in service or nearing completion. These projects, although conceived with a different purpose in view, will fill a need during the emergency for handling large centralized loads such as would otherwise tend to disrupt the diversified demands on utility systems. Uncertainty, however, often accompanies hydro power, as shown by the recent drought in the South with its adverse effect on TVA power.

Apparently the situation for 1943 is not so clear. Revised estimates of power requirements, based on the recently enlarged defense production program, indicate that the scheduled extensions to capacity may have to be revised upward. One official of the Federal Power Commission is quoted as estimating that a 20 per cent increase would be found necessary in the eleven North Atlantic states. This may prove too high, but the subject is now being carefully considered at regional conferences between representatives of the government and the utilities.

In a report dated June 12, the Commission states, "that unless orders are placed immediately for large amounts of additional capacity for 1943, serious shortages will develop in that year, and in subsequent years if the emergency continues."

Should the volume and the rate of placing government orders be still further increased, wider application of the three-shift system to all plants handling defense work would tend to alleviate the demands on power capacity. Finally, if it should eventually be found expedient to set up regional power administrators, as in the last war, they would exercise priority functions, in which case both the public and non-essential industries would have to put up with some inconvenience in the interests of common good.

It is unlikely that, in view of the close cooperation of all concerned, that power will become a serious bottleneck in defense production. Would that all other manufacturing facilities and the labor situation in the defense industries were as satisfactory.

Engineering News from Abroad

Some readers may have noted the occasional omission during some of the recent months of our department reviewing "Steam Engineering Abroad." The reasons are obvious. Not only have sinkings more or less disrupted the regular delivery of engineering periodicals from Great Britain, but the exigencies of war have prevented publication of much of the usual information concerning power plant work in that country. Little or nothing of importance appears to be taking place in the power plant field in France; and, although the German magazines continue to give attention to power subjects, their receipt in this country is becoming more irregular.

There is no intention of discontinuing this popular department, but during the prevailing situation it will appear only at such times as the literature received from abroad and the character of its contents, as pertains to the steam plant field, warrant a review.

Application of Heat Insulation

By E. C. HASSE

Materials Engineer,
The Commonwealth & Southern Corp.

A description of the methods employed by the utility system with which the author is connected in covering both high- and low-temperature piping, boilers, ducts, hoppers, air heaters, etc. A schedule for insulation thicknesses, as applied to various size pipe for different temperatures, is included, as are also sketches showing the procedure employed.

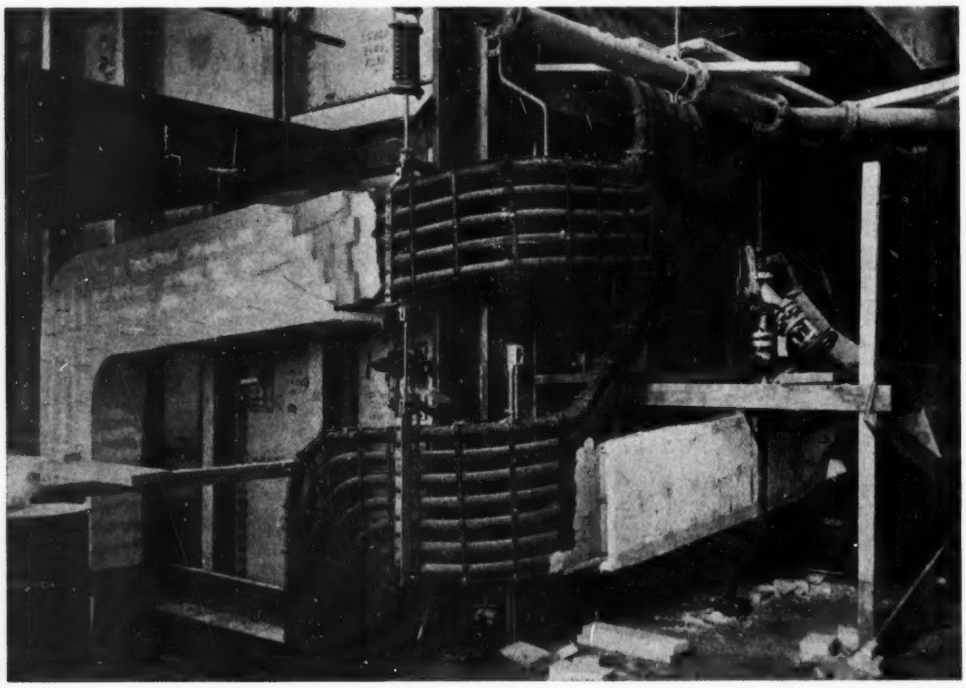
MUCH has been written regarding the heat-insulating values of various materials but to date little has been published as to practical ways of applying insulation. The following outlines the methods used by one of the public utility systems, without discussing relative merits of the various types of high- and low-temperature insulations and cements available.

As economically selected insulation thicknesses are a direct fuel saving, a careful analysis of fuel, steam and insulating costs is first made. From this study a schedule of thicknesses for various pipe sizes and temperature ranges is prepared similar to the representative schedule shown as Schedule *A* which covers average conditions. For temperatures below 500 F, low-temperature types of insulation are specified, and above 500 F, high-temperature types are used. Where fuel prices are high, greater thicknesses can be justified, and where low prices prevail, less insulation will prove more economical. In any case the selection should be the greatest standard thicknesses that will give a heat saving at least equal to the interest on the applied insulation investment.

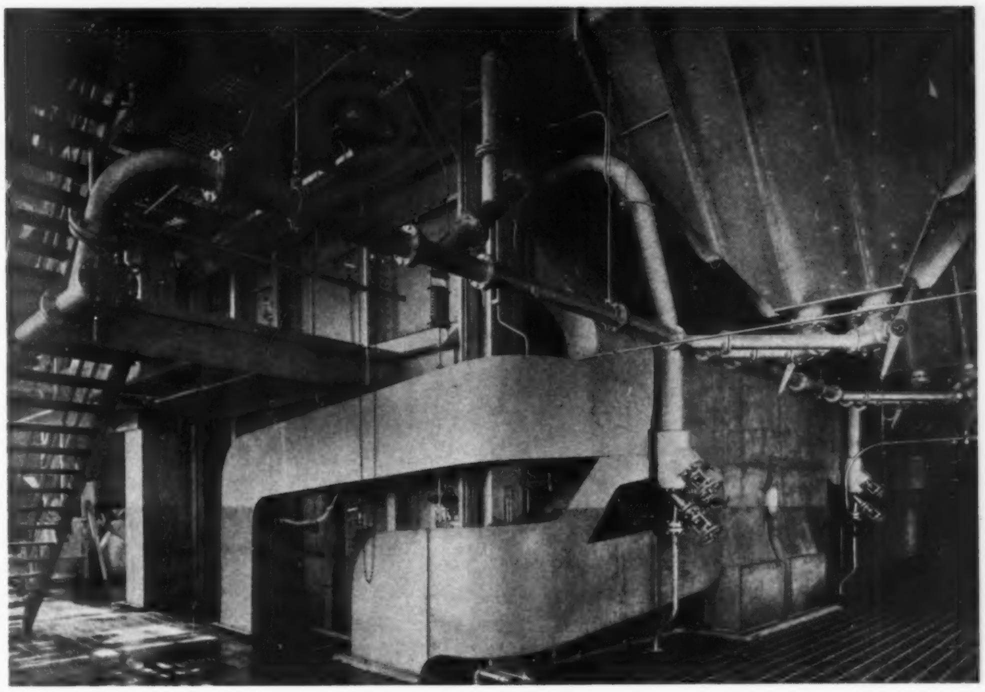
In Schedule *A* only pipe insulation thicknesses are shown but the same study is made for breeching, duct and pressure-vessel insulation thicknesses. The odd fractional thicknesses shown in this schedule are the nearest standard thicknesses that are available. Breeching and duct thicknesses usually vary between $1^1/_2$ and 3 in., depending on temperatures, and may be in single or double layers.

As piping is the most commonly insulated item it has received considerable attention. Good insulation being of a light and rather fragile nature must be expertly applied to give the best results. With sectional and block types a special effort should be made to obtain tight joints between sections and, where possible, through joints to the pipe should be avoided. In an effort to avoid through joints, double low-temperature and combination low- and high-temperature insulation is used as shown in Schedule *A*.

Piping to be insulated is first given a wire brushing to remove all adhering accumulations. Sectional insulation as specified for pipe size and temperature is then applied. All insulation should be wired in place, using No. 14 gage copperweld wire at a maximum of 16-in. intervals. Longitudinal joints in abutting sections



Group tube insulation in course of construction



Completed group tube insulation, including pipe insulation and showing outside appearance of hoppers

should be staggered. Both longitudinal and circumferential joints should be staggered where double layers are used. The contact ends of all insulation are buttered with a cement made of fibrous adhesive mixed with about 25 per cent by volume of insulating cement of the same general composition as the abutting sectional insulation. The cement assures contact between insulation sections and avoids through joints which would give passage for objectional heat loss. The use of cement on longitudinal joints was not found practical as it has sufficient thickness to prevent a tight fit of the insulation on the pipe. At all flanges short lengths of insulation are used to allow easy removal of flange bolts. On single thickness 6-in. lengths are used and on double thickness 6-in. lengths are used for the inner and 9-in. for the outer layer. Ends at flanges are beveled at 45 deg. This procedure gives a sharp edge for putting in repair insulation in case of damage due to bolt or flange removal; see Sketches 1 and 6.

SCHEDULE *A*

INSULATION THICKNESSES, INCHES

Pipe Size, Inches	Up to 350 F Low Temp.	350 F to 400 F Low Temp.	400 F to 500 F Low Temp.
3/4	7/8	1 1/2	2
1	7/8	1 1/2	2
1 1/4	7/8	1 1/2	2
1 1/2	7/8	1 1/2	2
2	1 1/32	2	2 1/2
2 1/2	1 1/32	2	2 1/2
3	1 1/32	2	2 1/2
4	1 1/8	2	2 1/2
5	1 1/2	Double Std.	3 (double 1 1/2)
6	1 1/2	" "	3 " "
8	1 1/2	" "	3 " "
10	1 1/2	" "	3 " "
12	1 1/2	" "	3 " "
18	1 1/2	" "	3 " "

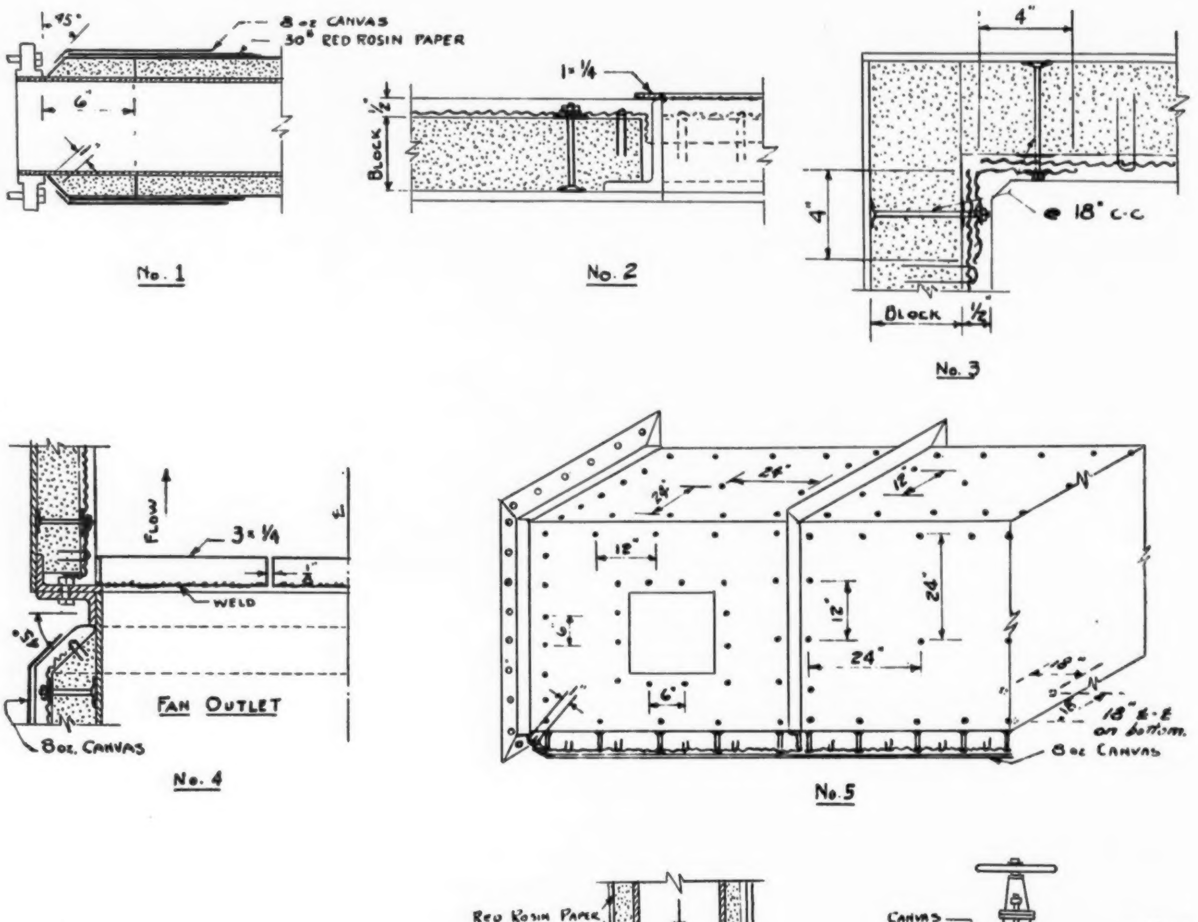
Pipe Size, Inches	500 F to 600 F High Temp.	Low Temp.	600 F to 800 F High Temp.	Low Temp.
3/4	2	None	2	None
1	2	"	2	"
1 1/4	2	"	2	"
1 1/2 and 2 (tube)	2	"	2	1 1/8
2 and 2 1/2 (tube)	1 1/4	1 1/2	1 1/4	2
2 1/2 and 3 (tube)	1 5/16	1 1/2	1 5/16	2
3 and 4 (tube)	1 9/16	1 1/2	1 9/16	2
4	1 9/16	1 1/2	1 9/16	2
5	1 1/2	2	1 1/2	2 1/2
6	1 1/2	2	1 1/2	2 1/2
8	1 1/2	2	1 1/2	2 1/2
10	1 9/16	2	1 9/16	2 1/2
12	1 9/16	2	1 9/16	2 1/2
18	1 1/2	2	1 1/2	2 1/2

Pipe Size, Inches	800 F to 900 F High Temp.	Low Temp.	Anti-Sweat Wool Felt
3/4	2	None	Two 1/2 layers
1	2	"	" " "
1 1/4	2	"	" " "
1 1/2 and 2 (tube)	2	1 1/8	" " "
2 and 2 1/2 (tube)	2 1/8	1 1/2	" " "
2 1/2 and 3 (tube)	1 13/16	1 1/2	" " "
3 and 4 (tube)	2 1/16	1 1/2	" " "
4	2 1/16	1 1/2	" " "
5	2	2	" " "
6	2 1/16	2	" " "
8	2	2	" " "
10	2 1/8	2 1/2	" "
12	2 1/8	2 1/2	" "
18	2	2 1/2	" "

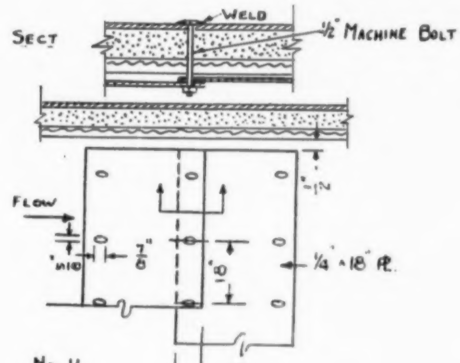
Where pipe bends are employed, sectional covering should be cut in short radial sections and applied in broken joint construction. If the pipe is too large for sectional covering, block insulation is used. A coat of insulating cement is applied over the wired-on insulation to give the covering a smooth unbroken contour.

Flanges, fittings and valves 3 in. and larger are insulated with block insulation fitted across the flanges as shown in Sketches 7 and 8. Block should be of the same material and thickness as adjacent pipe insulation. On fittings and valves the area between the block and fitting or valve body is filled with rock wool or crushed insulation. Blocks, as they are fitted, are cemented in place by buttering all contact edges with the fibrous adhesive cement and insulating cement mixture. The entire block assembly is held in place by careful wiring or by the use of rust-resistant Signode type straps. Insulating cement to a thickness of 1/2 in. is applied over the blocking to smooth the entire surface. Special care must be taken at all flange corners to give a smooth unbroken edge and contour. The use of an adjustable metal strip over the insulation is a means of obtaining true and plumb surfaces and edges. The strip is held in place temporarily and acts as a ground or striking edge for the finishing of the cement.

On fittings and valves under 3 in. and over 3/4 in., rock wool cement is employed in place of block insulation. The cement is applied in 1/2-in. layers to at least the thickness of the adjacent insulation. Over the rock wool a 1/4-in. layer of insulating cement is applied to cover up irregularities in the rock wool which cannot be



Sketches showing details



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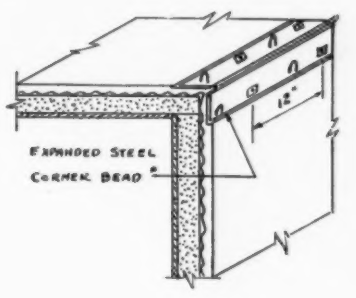

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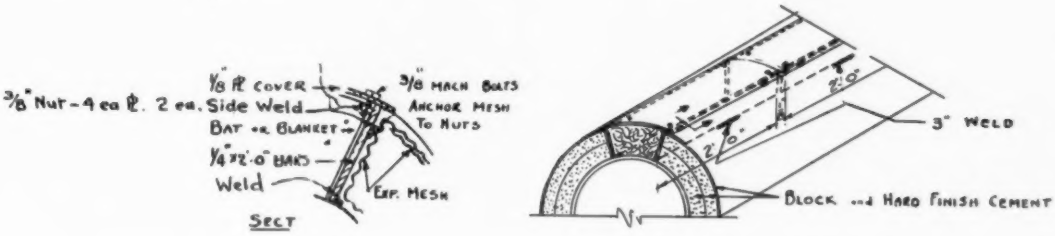

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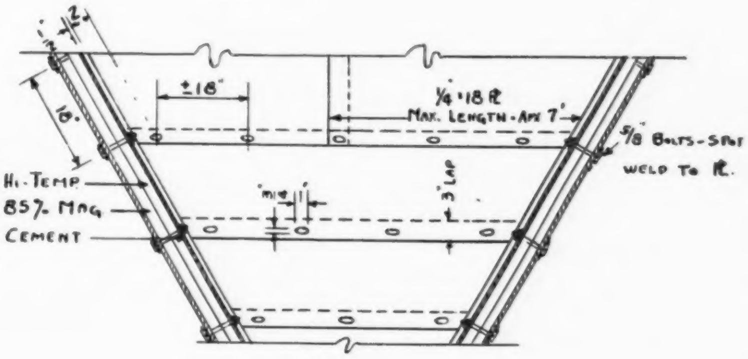

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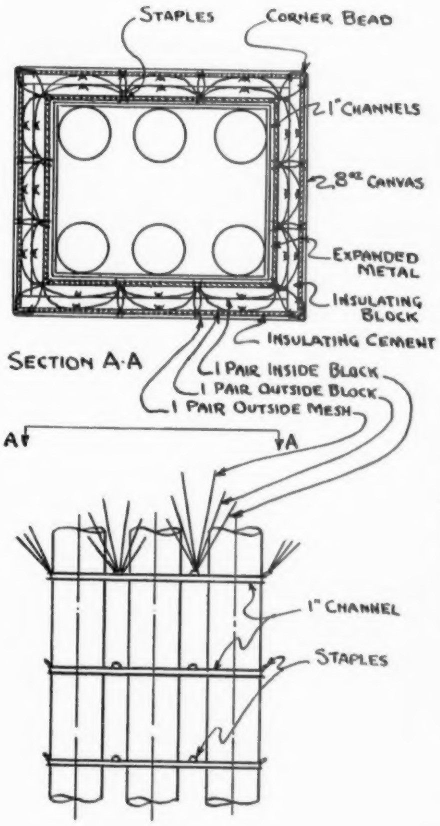

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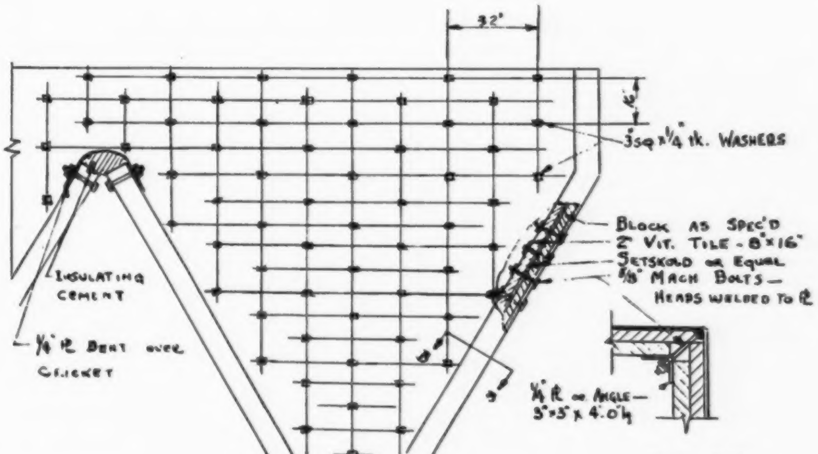


No 16

of insulation applications

troweled to a uniformly smooth surface. Unions 3 in. and under are not insulated. Valves and fittings $^3/_4$ in. and under are usually left uncovered.

It has been found advisable from both an appearance and a durability standpoint to recanvas all insulation. For this purpose 8-oz single-filled duck is used and, where practical, the duck is sewed in place by employing blind stitching with not less than two-and-one-half stitches per inch. A good grade of waxed twine should be used for stitching.

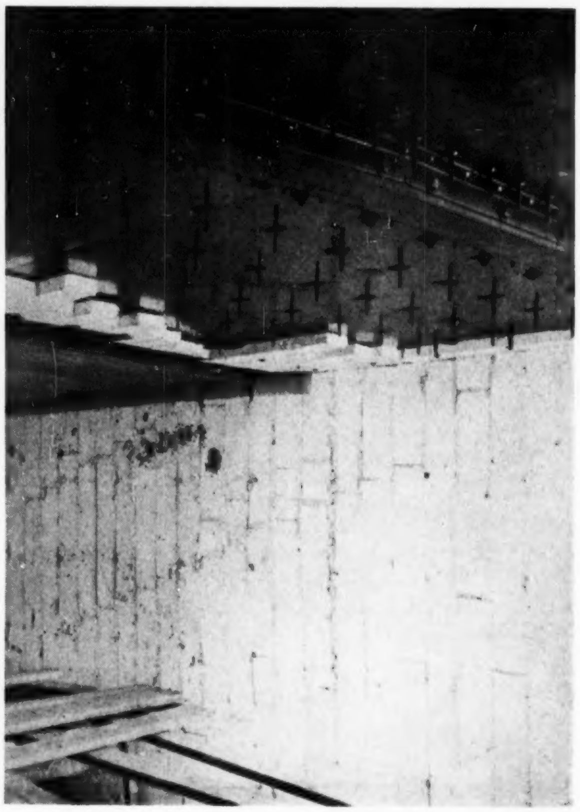
Before recanvasing, all straight runs of piping are covered with 30-lb per 500-sq ft red resin-sized paper tightly stapled in place. The edges of this type of paper may be bevel torn at all laps to give a smooth joint. Paper is not used on valves, fittings, flanges or bent pipe. The duck is next cut to size and applied to the pipe. As the sewing of the folded-in edges of the duck progresses, the staples in the paper are removed. The paper smoothes up all unevenness in the insulation and, if necessary, allows the sewed joint in the duck to be slid around the pipe to a position where it will be least noticeable. Great care must be taken in applying the duck on bent pipe to avoid any unnecessary circumferential seams and wrinkles. In recanvasing valves, fittings and flanges the duck is pasted in place to the smoothly finished insulating cement.

In all canvas work care should be taken to weather pasted laps so that water due to leaks, etc., will run over the joint rather than into the insulation. The joints between the pipe recanvasing and flange canvasing are sewed with a blind stitch as shown in Sketches 7 and 8. This sewing avoids unsightly gaps between flange and pipe insulation when the pipe is hot. After all recanvasing is in place, the duck surfaces are shrunk into place by applying cold water paint to which paste has been added. The paste acts as a size for future painting. While the paint solution is still wet the recanvasing on bent pipe can be worked into place to avoid wrinkles. To date no practical method has been devised that will eliminate all circumferential wrinkles in the recanvasing when high-temperature piping cools.

Boiler Insulation

On boiler insulation, exposed circulating tubing is often grouped so closely that the tubes cannot be insulated individually. Where this occurs tubes are insulated in a group as shown in Sketch 15. With this method 1-in. formed-steel channels are wired or spot-welded to the tubes at about 12-in. centers. Fence staples are welded to the channels at about 12- to 18-in. centers. Over the channels, weighing 3 lb per sq yd, expanded metal is applied and wired in place. The expanded metal is given a coat of cement suitable for the temperature involved. This cement coat is used to give a level surface for applying the block. Three pairs of wires are attached to each protruding staple if two layers of insulating block are required. If only one layer is needed, two pairs are used. Blocks in 6-in. widths are then applied to the cemented surface using fibrous adhesive to hold blocks in place while one pair of wires is used to fasten the blocks securely. All unused pairs of wires are carried out through successive layers of block. If a second layer is used, it is next applied without adhesive and wired in place with the second pair of wires. Over the block 3-lb expanded metal is applied and held firmly in place with the third pair of wires, and, where necessary, with $1^1/_2$-in. fence staples driven into the insulating block.

Where the cross-section is nearly circular, Signode-type straps are employed to hold the mesh in place. If the enclosure has a cross-section having corners, metal corner beads with expanded mesh legs are wired and stapled in place. Care must be taken to align the beads so as to give a neat finished job. Over the mesh, insulating cement is applied in two coats, giving a finished dry thickness of about $^1/_2$ in. The corner beads, if used,



Inside breeching insulation in course of construction

act as a screed for the finish cement coat and also give a hard corner which is not easily damaged. Over the finish cement 8-oz duck is pasted in place as the final finish before painting. This method is quite simple to apply and lends itself to all types of irregular enclosures.

Exposed boiler drum ends are insulated with block, fitted, cemented and wired in place. Over the block 3-lb expanded metal is fitted and held in place with Signode-type straps and wiring. Around manhole openings a $^1/_4$-in. thick bar of the total insulation thickness width is bent to shape and tack-welded to the boiler drum Around the outside edge of the bar $^3/_8$-in. square nuts are welded to form anchors for tying the holding wires. The mesh is given two coats of insulating cement troweled to a smooth surface. Over the cement a 20-gage galvanized sheet metal casing is applied. The casing is made in orange-peel sections held together with sheet metal screws. Laps in casings should be weathered to prevent any leakage flowing into the insulation.

Boiler headers having handholes are provided with welded enclosure bars as shown in Sketch 13. The bars are made in about 2-ft lengths and each is provided with four $^3/_8$-in. square nuts. Two nuts hold the cover plate and two nuts are used to anchor the wiring that holds

the header insulation in place. Two-foot lengths are employed as the header expansion will break the welds if long sections are applied. An easy application method is to apply long lengths with nuts in place and then section the bar at pre-marked points with a cutting torch. This gives perfect alignment which is rather difficult with a series of short lengths. With the cover plates in two-foot lengths, easy access is available to any section of the header. Insulation over the header handholes is either in short blanket form or else rock wool cement. The rock wool is much more economical and is easily removed and may be re-used. The blanket is more convenient as its removal leaves a clean handhole cover which is immediately available. The blanket is also much easier to replace.

On header insulation expanded metal as shown in Sketch 13 is applied before putting on the finish cement coat. A narrow section of mesh is bent and put in place under the first layer of insulating block. The protruding end is bent over the expanded metal on the header and the entire mesh assembly held in place with wires from the $^3/_8$-in. square nut anchors. This procedure has been found desirable as the insulation has a tendency to rise up and pull away from any hot abutting metal. To finish the header, canvas is pasted to the insulation finish cement.

The use of canvas covers up cracks in the insulation which may develop after continued use. It also gives a surface resistant to damage due to ladders, foot traffic, etc. In applying canvas on heat insulation it should terminate about 1 in. from any protruding metal to avoid danger of burning; see Sketches 1 and 6.

Anti-Sweat Insulation

In power-plant work, cold water piping and containers cause considerable nuisance due to sweating during high humidity periods. To avoid this condition anti-sweat insulation should be used. The procedure outlined should not be confused with refrigeration types of insulation which must be given special attention to insure perfect moisture-proofing.

All fittings, valves and flanges are covered with a minimum of either two $^1/_2$-in. layers of hair felt tied in place with 8-ply jute twine or two $^1/_2$-in. layers of sectional anti-sweat insulation fitted and wired in place with No. 14 gage copperweld wire. Insulation is to be applied with broken joint construction similar to previously described heat insulation. Flanges are built up with square edges. Entire valve and fitting bodies are built up in box form as shown in Sketch 10. Flanged valve and fitting bodies, other than ells, are built out with hair felt to the outside diameter of the flanges and then covered with two $^1/_2$-in. layers of anti-sweat insulation wired in place. Elbows are built up between flanges with $^1/_2$-in. layers of hair felt carefully tied in place. Over the hair felt two $^1/_2$-in. layers of anti-sweat are fitted and wired in place, and two $^1/_4$-in. layers of insulating cement are applied to give a smooth uniform finish. The piping is canvased with 8-oz duck sewed in place. Valve and fitting insulation is finished with duck covering pasted in place and all edges of pasted canvas are trimmed to a neat uniform contour with all pasted laps weathered by having the upper duck lap over the lower. Pipe canvasing is sewed to the flange duck the same as for other types of heat insulation.

Where pipe insulation passes through openings in floors and where it is subject to damage due to traffic, a protection sleeve is installed as shown in Sketch 9. The sleeves are made of 22-gage galvanized iron held in place with sheet-metal screws. The top of the sleeve is crimped to give a snug fit to the canvasing. Sleeves should not be applied too tightly as they will retard the movement of the recanvasing during expansion and contraction of the piping.

On large surfaces such as condensers, circulating pumps and piping, it is often a problem to avoid excessive sweating. This condition is taken care of by applying a varnish type of paste and granulated cork mixture. The paste is put on with a spray gun and the cork with air blast. Paste and cork are applied simultaneously to a thickness of from $^3/_8$ to $^5/_8$ in. This gives a good durable surface which can be finished with several coats of sprayed-on oil paint.

Inside Insulation for Breechings and Ducts

Breeching, duct and flat surface heat insulation has been a source of continual annoyance due to unsightly appearance and lack of durability. After considerable study it was concluded that wherever practical, inside insulation would be used. This method eliminated to a great extent cracking and buckling due to expansion and contraction of the steel plates. The steel outside surface is also easy to paint and maintain.

For holding inside insulation in place the first step is to wire-brush all surfaces to remove loose scale, rust, etc. Next, $^3/_8$-in. countersunk-head stove bolts are welded around the head on the inside of the platework. On all horizontal surfaces except the top, bolts are placed at 24-in. centers both ways. On vertical and inclined surfaces 18-in. centers are used. On top surfaces and curved sections of vertical surfaces the bolt spacing is on 12-in. centers. Bolts are $^1/_2$ in. longer than the insulating block thickness. At all corners formed by intersecting plates, bolts at the specified spacing for adjacent plates are welded on both sides of and as close as practical to the intersection; see Sketch 3. Around all openings and where insulation stops at angles, expansion joints, etc., a row of bolts at 6-in. centers is welded as close as practical to the terminal edge of the insulation. Bolt locations should be carefully laid out so they will come at the center line or edges of the block width to be used. For ease of handling and application, 6-in. widths seem to work very well.

After the bolts are in place the predetermined thickness of insulating block is ready for application. Each block is given a trowel coat of fibrous adhesive cement over the entire contact surface just before application. Steel washers, $2^1/_2$ in. square by $^1/_8$ in. thick, are placed over each bolt after the blocks are in place. On overhead work a small amount of adhesive is placed on the block side of the washer and a nut temporarily screwed on the bolt to hold the washer in place until the cement sets. Nuts are removed as soon as the cement has set. Over the washers, 3-lb expanded-metal lath is applied with not less than 2-in. laps. Mesh is easily forced over the bolt ends with a hollow punch. A $1^3/_8$-in. diameter by $^3/_{32}$-in. thick washer is next put on the bolt end and a half thickness $^3/_8$-in. square nut screwed into place. The nuts are turned up tight enough to partially embed the underlying square washer in the insulation. They

Tile hopper lining insulation

may be quickly turned up with a socket wrench in a carpenter's brace. The protruding end of the bolt is closely clipped off with a bolt clipper, the clipped end acting as a lock nut. In addition to the bolting, $1^1/_2$-in. fence staples are driven through the mesh, about half as many staples as bolts being used. At all corners 8-in. wide machine-formed corner strips of expanded metal are now applied using the bolts that were provided for this purpose; see Sketch 3. At all terminal edges and around all openings the mesh should be turned down 1 in. to give a rigid edge which will not bulge out due to heat; see Sketch 2. Over the expanded metal two coats of abrasive-resistant cement are applied to give a final dry thickness of at least $^1/_2$ in. A vitreous type of cement is best suited where breechings carry hot cinder-laden gas. Care should be taken to see that bolt ends are well covered with cement. Expansion joints are not covered. At all openings a $1 \times {}^1/_4$-in. flat bar frame is spot-welded in place to hold down the insulation; see Sketch 2.

Where insulation ends at expansion joints or there is transition from outside to inside insulation, $3 \times {}^1/_4$-in. bars in about 3-ft lengths are welded in place. These bars are put on the downstream side of the gas flow to prevent the insulation lifting up and being torn out of position by the gas blast. This precaution is essential especially in breechings as cinders and soot start depositing under any loose insulation and soon break it loose; see Sketch 4.

Where breechings bend and where severe abrasion is expected additional protection in the form of $^1/_4$-in. thick plates is applied over the finish cement coat. Plates 18 in. wide are drilled as shown in Sketch 11 and applied with 3-in. laps weathered in the direction of the gas flow. Holes in the plates are marked on the cement and $^9/_{16}$-in. diameter holes drilled through the insulation and breeching plate. One-half inch machine bolts are next inserted from the outside of the breeching and seal-welded around the heads. A $^1/_2$-in. washer is placed on the threaded end of the bolt and snugly tightened down with a $^1/_2$-in. square nut. The ends of the bolts are clipped off. This method allows the plates to expand and contract and also makes replacement easy.

Hopper Insulation

Where high-heat cinder and soot hoppers require abrasion resistance and heat insulation a successful method has been developed which to date is giving excellent results. Hoppers are first lined with the required insulation using fibrous adhesive for attaching blocks to the platework. Adhesive is also used between the layers of insulation if two layers are required. The high-temperature type of insulating block is always placed as the second layer, if two layers are required. Over the insulating block second quality 8×16-in. vitreous hollow tile 2 in. thick are placed as shown in Sketch 16. Two of the diagonally opposite corners of each tile are chipped or cut off to provide clearance for the $^5/_8$-in. holding-down bolts. At intersections tile must be cut to fit the intersection. The cutting is easily done with a tile setter's motor-driven cutting wheel. All tile is bedded into a cold-setting high-temperature cement. Holes $^{11}/_{16}$-in. in diameter are now drilled through the openings at the tile corners, the holes extending through the insulation and the hopper plates. Next, $^5/_8$-in. bolts are inserted through the holes from the plate side and 3-in. square, $^1/_4$-in. thick washers and square nuts are applied. The nuts are then pulled up snug to bed the tile into the cement. Tapped holes and threaded studs are used where bolts cannot be inserted from the outside. At the hopper corners $^1/_4$-in. formed plate angles are attached with bolts which have been welded on the inside of the hopper as shown in Sketch 16, Section *BB*. Tops of crickets are covered with $^1/_4$-in. bent plate bolted in place as shown. Ends of the bolts are clipped off and bolt heads on the outside of the hopper are seal-welded. The tile lining is easy to maintain as individual tile can be replaced. Nuts can be readily removed, even after long service, by splitting them with a cutting torch. For less severe service the methods shown in Sketch 14 using $^1/_4$-in. plate may be used.

In none of our inside insulation work have we experienced any difficulty due to heat transfer through the holding-down bolts charring our aluminum finish painting of the steel platework. Temperatures up to 1000 F are often attained in the economizer hoppers.

Outside Insulation on Fans, Economizers, Air Heaters, etc.

Where outside insulation is found necessary as on induced-draft fans, cinder eliminators, air heaters, economizers, ducts subject to water damage, ducts too small for inside insulation and some cold air ducts, the following procedure is employed:

Three-eighth inch countersunk head bolts are welded as shown in Sketch 5. Along both sides of all stiffener angles and channels, and along both sides of all corners and projections, bolts are welded at 12-in. centers and as close as practical to the edges. Along all terminal edges, bolted connections, and around all openings, the bolts are welded on 6-in. centers. Bolts are also welded at not more than 24-in. centers on all side and top areas and at not more than 18-in. centers on all the bottom plates.

Insulating blocks are then fitted and cemented in place with fibrous adhesive cement. Over the block, 3-lb expanded metal lath is applied using square and round washers as outlined for inside insulation; see Sketch 2 for general details. At all corners galvanized, expanded-metal leg corner beads are securely bolted, wired and stapled in place; see Sketch 12. Beads must be carefully aligned as they form the striking edge for the finish plaster coat. A little extra care with the corner beads is well repaid by the neat appearance of the finished job. Over the expanded metal two coats of insulating cement are applied to give a dry cement thickness of at least $^1/_2$ in.

At all bolted joints the insulation and the cement coat are tapered down to 45 deg to give access to the bolting; see Sketch 4. To avoid damage to insulation and to give a good painting surface, the finish cement is covered with 8-oz duck, carefully pasted in place. This duck is kept at least 1 in. from all hot metal to avoid charring. In pasting on duck, the same care is taken as in pipe work to weather all pasted joints and make all fitted joints with a neat uniform contour.

Tanks and cylindrical pressure vessels are insulated in the same general manner as for outside insulation except that in most cases bolts can be omitted and Signode-type straps used. Metal lath and corner beads are used wherever practical as they have been found a very desirable feature in keeping insulation in place. Where openings such as manholes and inspection plates occur, $^1/_4$-in. thick steel bar frames are tack-welded to the steel to give a permanent terminal edge for the surrounding insulation. Where wiring is found necessary, as on dished-head pressure vessels, nuts are welded to the insulation side of the bar to anchor the wiring.

After numerous trial and error experiences we have found that the investment in good insulating materials carefully applied is well worth while. Some of our procedures may seem rather unessential, but the fact that rather fragile material can be securely held in place and give the expected service year after year is in our opinion ample justification.

Additions to Power Supply

The Federal Power Commission has issued a report, as of April this year, giving the scheduled additions to generating capacity for public use. Additions contemplated for completion during 1941 total 3,352,639 kw and for completion subsequently 3,217,477 kw. Part of the latter will go into service in 1942 and most of the remainder in 1943. The total budgeted expenditures for the present year are $868,209,000.

Of the 1941 additions, 2,351,142 kw represents fuel burning installations and 1,001,497 kw hydro, most of the latter being in publicly owned plants. Arranged geographically this capacity is as follows:

	Fuel	Hydro
New England	146,500	1,500
Middle Atlantic	532,566	..
East North Central	850,634	1,050
West North Central	133,505	2,512
South Atlantic	381,543	125,815
East South Central	72,776	90,000
West South Central	22,559	67,500
Mountain States	70,457	222,660
Pacific	140,602	490,460

Symposium on Determination of Steam Purity

During the Forty-fourth Annual Meeting of the American Society for Testing Materials, June 23–27, at the Palmer House, Chicago, there will be a symposium on problems and practice in determining steam purity by conductivity methods. Many problems have arisen in connection with the determination of steam purity by conductivity methods, but its possibilities of exactness and its adaptability for use with recording instruments have encouraged comprehensive research work to obviate them. This timely symposium, scheduled for June 26, will comprise the following technical papers:

"The Sampling of Steam and Boiler Water," by A. R. Belyea and A. H. Moody, Consolidated Edison Company of New York, Inc.

"Experimental Methods of Determining Conductivity Correction Factors for Dissolved Gases in Steam Condensate," by S. F. Whirl, Duquesne Light Co.

"Calculation of Corrections to Conductivity Measurements for Dissolved Gases," by D. S. McKinney, Carnegie Institute of Technology.

"The Degasification of Steam Samples for Conductivity Tests," by P. B. Place, Combustion Engineering Co.

"A New Type of Conductivity Apparatus for Use with Boiler Waters and Steam Samples," by A. R. Mumford, Consolidated Edison Company of New York, Inc.

Coal Prices Studied

The Bituminous Coal Division of the Department of the Interior has announced revised preliminary estimates of average prices at the mine which producers received from the sale of coal during the nine months of 1940 which ended on October 1, the date minimum prices became effective.

There was little change in the previously estimated average price for the nation as a whole, which indicated that producers sold their coal during the nine-month period at prices averaging approximately five cents per ton below the 1940 cost of production for all mines.

Steam Generating Plant of the Atlantic Gelatin Company, Inc.

By **ALBERT A. FAVA,**
Chief Operating Engineer
Atlantic Gelatin Company, Inc.

Exterior of boiler plant

The process of gelatin manufacture, as reviewed, involves a large quantity of process steam which is supplied by two 65,000-lb per hr, two-drum oil-fired boilers designed for 300-lb pressure but operating at 150 lb initially. The boilers have automatic control and are equipped with air preheaters. Performance data are included showing efficiencies from 85.6 to 87.6 per cent.

GROWTH of the gelatin industry in the United States has been remarkable due to the many diversified uses that have been developed for this product in the food industry, in the pharmaceutical field, in the preparation of photographic materials, in culture media for bacteriological work and in innumerable other applications in commerce and industry. The annual output is valued at millions of dollars.

Of the total annual production, the Atlantic Gelatin Company manufactures approximately 25 per cent. This company was organized in 1919 and is located in the wooded, sparsely settled section of Woburn, Mass. At this plant, probably the most modern of its kind, the process of manufacture is conducted along strictly scientific lines, supplemented by extensive laboratory work.

Gelatin is a protein substance, derived from the supporting tissues of the animal body, such as the skin, bones and connective tissue. These substances contain collagen which is converted into gelatin upon hydrolysis. Gelatin is not made from horns, hoofs or hair, which contain keratin but not collagen. It is rich in nitrogen, about 18 per cent, and low in sulphur; and when broken down into its corresponding amino acids, it contains most of those essential for nutrition such as glycine, proline, oxyproline, but not tryptophane and tyrosine. When collagen is treated with acid or alkali in the presence of water it is converted into gelatin which can then be extracted with the aid of heat; that is, the process is essentially similar to the preparation of soup in the home.

Preparation of Gelatin

The raw product is first washed in pure water until it is free of all foreign particles. If it consists of calf skins, they are removed, after thorough washing, to liming vats, treated with a fresh lime solution and allowed to remain from 60 to 90 days. They are then removed to secondary cleansing vats where all traces of lime are removed by prolonged washing in water and subsequent neutralization. At this point the gelatin is ready for extraction. The treated raw stock is placed in aluminum cookers, covered with distilled water and the gelatin extracted with the aid of heat. When this step is completed, a soup containing 4 to 5 per cent gelatin, dissolved in water, is available. This is filtered under pressure to remove any suspended matter or impurities and the filtered gelatin solution is passed to an aluminum evaporator where the excess water is removed by evaporation under vacuum. This is followed by a second filtering.

Throughout the entire process the gelatin is kept at a minimum temperature of 145 F in order to pasteurize it. After the second filtering operation it is cooled rapidly to about 100 F and allowed to flow onto an endless belt which passes through a closed chilling chamber. When it emerges from the chilling chamber the gelatin is cut into uniform strips and passed on to sterile aluminum wire nets which are placed in closed drying tunnels through which warm dry air is constantly circulated. The gelatin is then removed, without coming in contact with human hands, and passes to breaking machines. It is then ground, screened to uniform size and packed.

All piping valves, etc., are of aluminum, and immediately after a batch of gelatin is prepared all tanks are thoroughly cleaned, and the piping disconnected, cleaned and sterilized. The same applies to the belt and nets. Furthermore, the process of manufacture is supervised and controlled by chemical and bacteriological examinations conducted by the laboratory staff.

From the foregoing outline of the process it will be

apparent that considerable quantities of steam are required. Up to July 1940 this steam was purchased from a nearby Woburn plant, although electric power was and still is purchased from the public utility system. By 1939 the steam load had reached a peak of 30,000,000 lb per month with resultant high cost. It then seemed advisable to look into the possibility of constructing a steam-generating plant to meet the increasing steam requirements.

Initial Operations Provide for Steam Generation and Purchased Power

A number of possibilities ranging from a simple boiler plant to the complete generation of electric power were considered. It was finally decided to install two 300 lb pressure, oil-fired steam generators to operate at 150 lb pressure, together with the necessary auxiliary equipment, and to continue purchase of electric power from the public utility system. The plant was designed on this basis and was put into operation on June 24, 1940.

Fundamentally, the new steam plant was predicated on the generation of steam for processing at a lower cost per 1000 lb than steam had been costing, with additional provision for power generation if and when this should appear economical. Therefore, although initial operation with 150-lb saturated steam was decided upon, equipment was selected capable of operating at 300 lb. That this proposal was sound is shown by the actual performance which, under the writer's charge, bettered the original estimates of savings by exceeding the manufacturer's guarantee on the steam generators of 85.3 per cent efficiency at maximum continuous output.

HEAT BALANCE NO. 1 UNIT

Readings given are the average per hour of 12 readings taken between 2:00 p.m. and 3:00 p.m. November 23, 1940, with the unit under automatic control.

Steam flow, lb per hr	48,800	
Steam pressure, lb per sq in.	150	
Feedwater temperature, F	230	
Fuel oil service meter, gal	378	
Fuel oil temperature, F	220	
Boiler exit gas temperature, F	525	
Air heater exit gas temperature, F	330	
Temperature of air to air heater, F	84	
Temperature of air from air heater, F	340	
Flue gas analysis, CO_2, per cent	13.0	
O_2, per cent	3.9	
Total air, per cent	121.5	
Fuel oil analysis, C, per cent	85.8	
H_2, per cent	12.0	
S, per cent	2.0	
$N_2 + O_2$, per cent	0.2	
Btu per lb	18,433	
Lb per gal	8.07	
Calculated Values		
Oil consumed, lb	3050	
Actual evaporation, per lb of oil	16	
Factor of evaporation	1.028	
Equivalent evaporation, per lb of oil	16.448	
Heat absorbed by boiler, per lb of oil, Btu	15,961	
Evaporative efficiency, per cent	86.59	
Loss due to moisture	nil	
Loss due to burning H_2	1109.2 Btu or 6.01 per cent	
Loss in stack gases	19.4 lb dry gas per lb of C 982 Btu per lb of dry fuel 5.32 per cent	
Loss due to moisture in air	24.0 Btu or 0.13 per cent	
Loss due to radiation	276.5 Btu or 1.5 per cent	
Unaccounted losses (assumed)	184.3 Btu or 1.0 per cent	
Summary of Losses	Btu	Per cent
Loss due to H_2	1109.2	6.01
Loss in stack gases	982.0	5.32
Loss due to moisture in air	24.0	0.13
Loss due to radiation	276.5	1.5
Loss unaccounted	184.3	1.0
Total losses	2576.0	13.96

EFFICIENCY BY DIFFERENCE

18,433 − 2,567.0 = 15,857 Btu

$$\frac{15{,}857}{18{,}433} = 86.04 \text{ per cent absorbed by boiler}$$

HEAT BALANCE NO. 2 UNIT

Readings given are the average per hour of 12 readings taken between 10:36 a.m. and 12:36 p.m. April 26, 1941, with the unit under automatic control.

Steam flow, lb per hr	51,600	
Steam pressure, lb per sq in.	150	
Feedwater temperature, F	233	
Fuel oil service meter, gal	389.5	
Fuel oil temperature, F	210	
Boiler exit gas temperature, F	540	
Air heater exit gas temperature, F	335	
Temperature of air to air heater, F	84	
Temperature of air from air heater, F	360	
Flue gas analysis, CO_2, per cent	12.4	
O_2, per cent	4.9	
Total air, per cent	129.0	
Fuel oil analysis, C, per cent	85.8	
H_2, per cent	12.0	
S, per cent	2.0	
$N_2 + O_2$, per cent	0.2	
Btu per lb	18,422	
Lb per gal	8.16	
Calculated Values		
Oil consumed, lb	3178	
Actual evaporation, per lb of oil	16.23	
Factor of evaporation	1.024	
Equivalent evaporation, per lb of oil	16.62	
Heat absorbed by boiler, per lb of oil, Btu	16,138	
Evaporative efficiency, per cent	87.60	
Loss due to moisture	nil	
Loss due to burning H_2	1111.79 Btu or 6.03 per cent	
Loss in stack gases	20.3 lb dry gas per lb of C 1049 Btu per lb of dry fuel 5.69 per cent	
Loss due to moisture in air	23.9 Btu or 0.13 per cent	
Loss due to radiation	276.3 Btu or 1.5 per cent	
Unaccounted losses (assumed)	184.2 Btu or 1.0 per cent	
Summary of Losses	Btu	Per cent
Loss due to H_2	1111.79	6.03
Loss due to stack gases	1049.00	5.69
Loss due to moisture in air	23.90	0.13
Loss due to radiation	276.30	1.50
Loss unaccounted	184.20	1.00
Total losses	2645.19	14.35

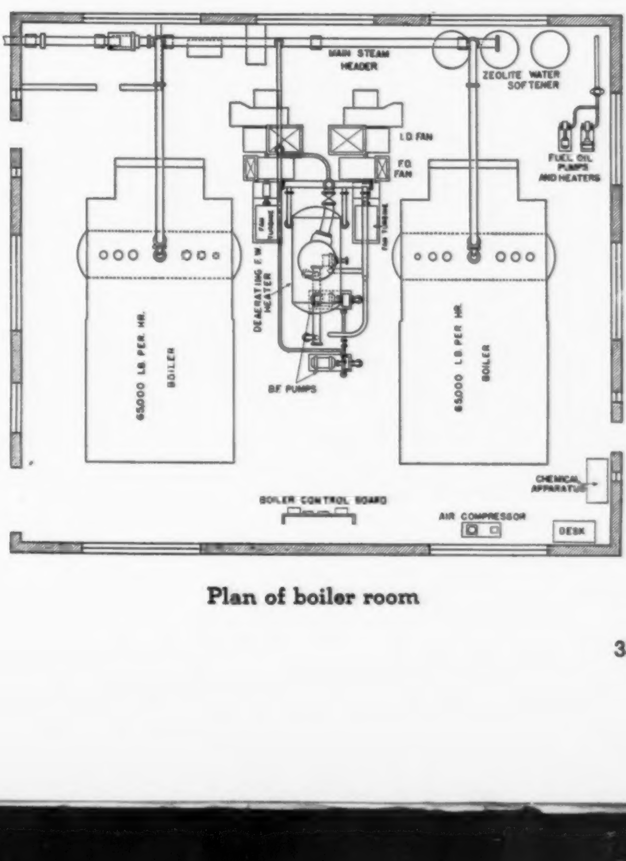
EFFICIENCY BY DIFFERENCE

18,422 − 2,645.19 = 15,776.81 Btu

$$\frac{15{,}776.81}{18{,}422} = 85.65 \text{ per cent absorbed by boiler}$$

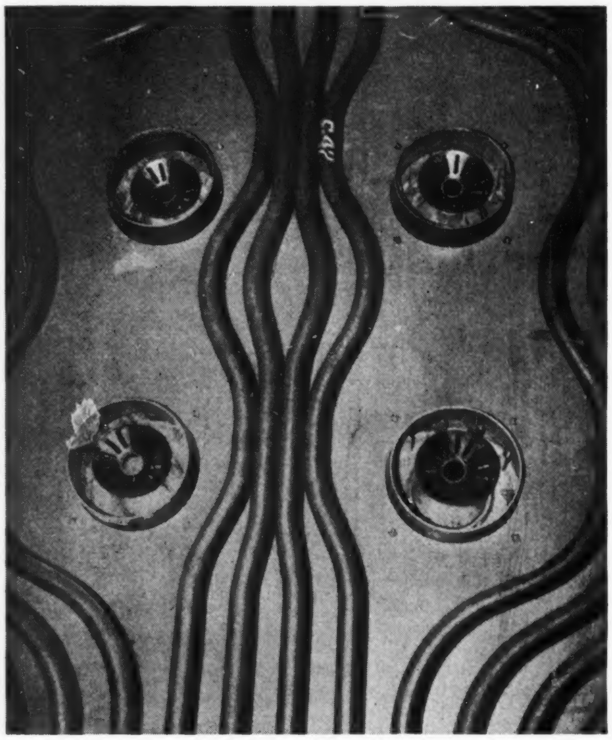
(Predicted Performance = 85.8 per cent)

The plant consists of two Combustion Engineering steam generators of the two-drum VU type, designed for 300 lb pressure and 65,000-lb per hr continuous output each, when operating initially at 150 lb pressure and 250 F feedwater temperature. Each unit has a 3540-sq ft tubular air heater and is fired with four Woolley mechanical-type oil burners operating at 100 to 225 lb pressure, and controlled by a Bailey master controller located at the panel board. Also, at the panel board are two Bailey flowmeters, two Hays five-pointer draft gages, one Republic flowmeter for recording steam flow to the factory, one Foxboro combination pressure and water-



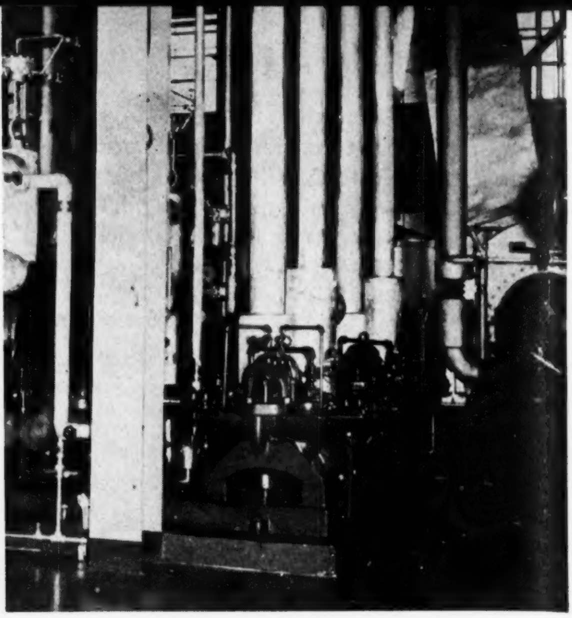
Plan of boiler room

Views Inside Boiler Plant at Atlantic Gelatin Co.

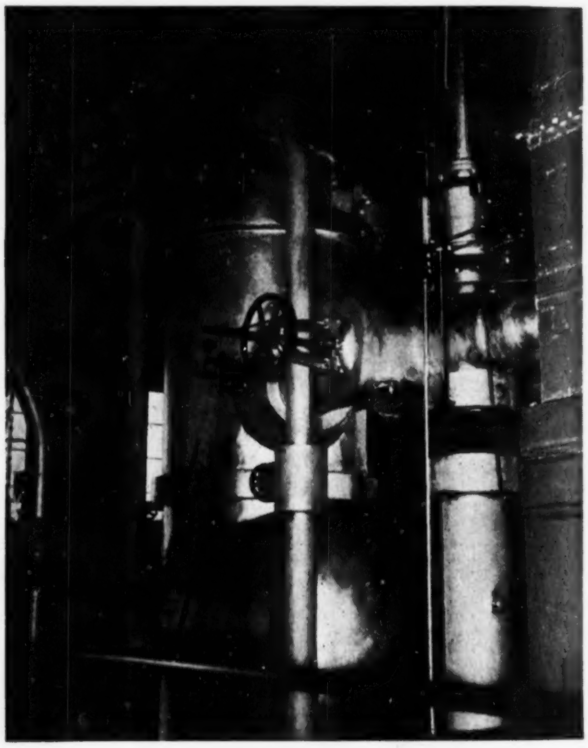


Inside of furnace showing burners

Zeolite water softener and fuel-oil pumps

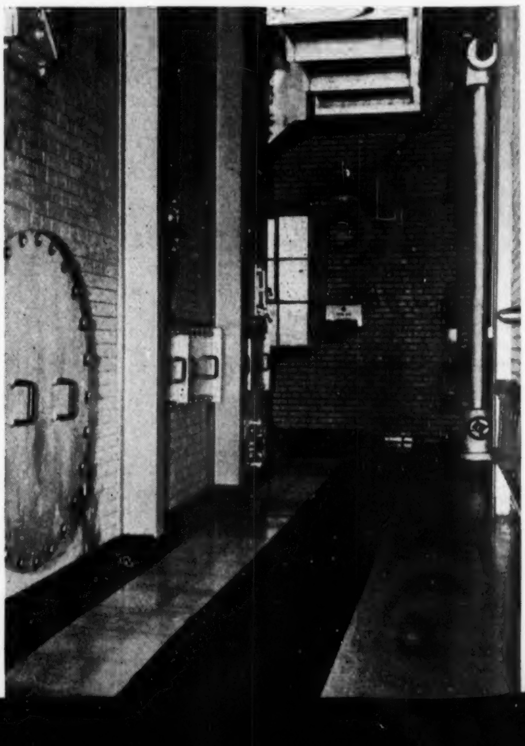


Turbine-driven feed pumps; forced-draft fan in rear



Top—Deaerating heater and atmospheric relief valve

Bottom—End of boiler setting showing general neatness of plant



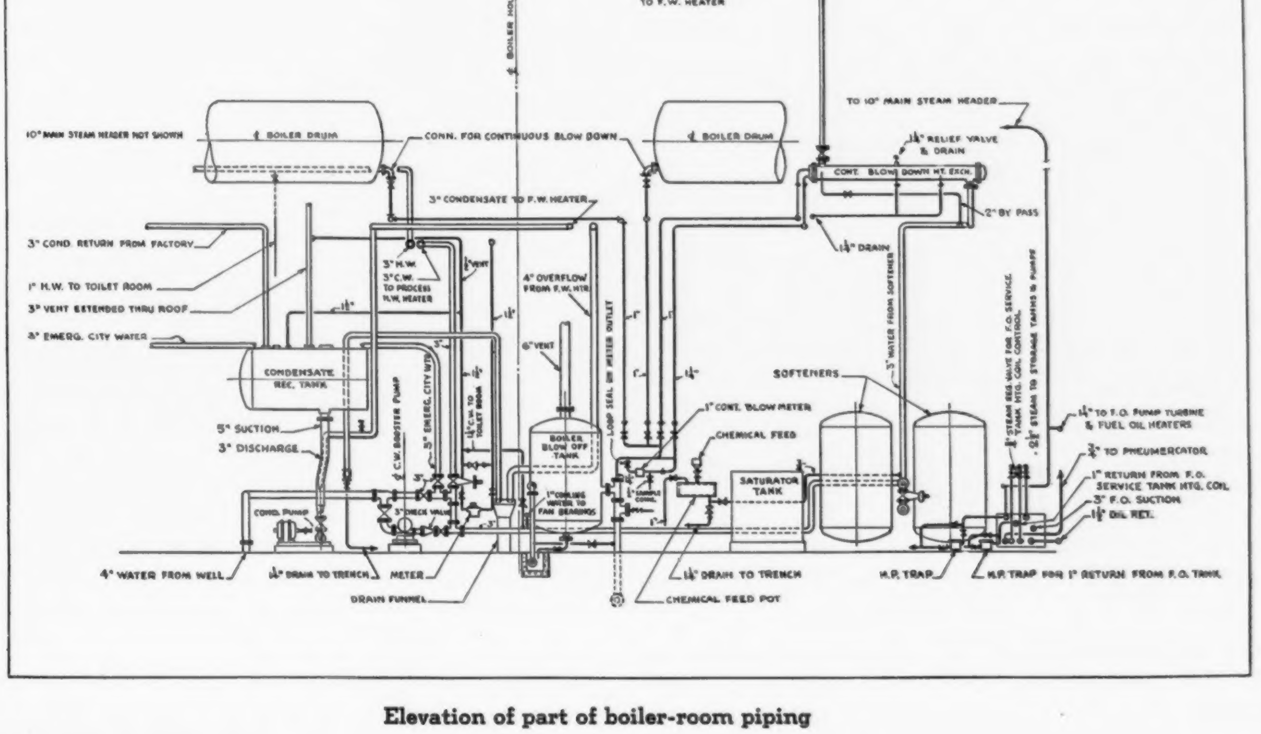
temperature recorder and two Foxboro combination air-and-gas temperature recorders. Bailey selector valves which control, either manually or automatically, the fan speed, induced draft and fuel supply to the burners are also located on the panel board—all controlled by the master controller.

Two Sturtevant duplex forced- and induced-draft fans connected on a common shaft and driven by 55-hp Elliott turbines with reduction-gear drives supply air at 15,900 cfm and 28,800 cfm, respectively.

The boilers are fed by two DeLaval centrifugal feed pumps of 150-gpm capacity, driven by 38-hp Elliott turbines having Fisher differential pump governors and controlled by Bailey water regulators. Forty-seven per cent of the water fed to the boilers is condensate returns and is pumped directly to an Elliott deaerator of 65,000 lb per hr capacity by a Micro-Westco 65-gpm centrifugal pump. Of the water fed to the boiler 53 per cent is makeup and is taken from a deep well having approximately 8 grains hardness per gallon. This water is pumped by a Worthington centrifugal pump through two Scaife zeolite water softeners each having a capacity of 70 gpm. The raw water at 55 F is then passed through a Paracoil continuous blowdown heat-exchanger and is heated to about 100 F before entering the deaerator where it is heated to 230 F.

The fuel-oil system was designed with a view toward practicability. Two 50,000-gallon vertical cylindrical and one 11,600-gallon horizontal cylindrical tanks were constructed with loading facilities from either railroad tank car or truck delivery. Each 50,000-gallon storage tank is equipped with the necessary safety devices. Attached to the outside of each tank is a gage board, which, operated by a float, indicates the number of inches of fuel oil in the tank as measured from 0 to 256 in. An instantaneous Paracoil U-tube suction-type heater was installed on each storage tank with steam to each heater manually controlled. The service tank is equipped with a coil heater and controlled thermostatically by a Foster regulator. A Pneumeracator depth gage indicates the oil level in the service tank, which can also be sounded by a measuring stick. Running adjacent to the steam plant is a railroad siding which is conveniently utilized in the delivery of fuel oil. A roadway was constructed to permit loading of the oil-storage tanks by trucks.

Fuel oil when received from either tank car or truck delivery is pumped by two Warren horizontal duplex fuel-oil pumps of 100-gpm capacity, to either the storage or service tank. In order to eliminate the transfer of fuel oil from tank car or truck through the fuel-oil pumps to the service tank, a roadway was built to the service tank, permitting dumping of fuel oil directly from trucks into the service tank, and also utilizing the heat of fuel oil as delivered by trucks at 120 F which eliminated the necessity of heating the oil in the service tank. From the service tank the fuel oil enters the plant through two DeLaval IMO rotary pumps of 12-gpm capacity. One unit is driven by a Westinghouse 5-hp motor and the other unit by a Wing steam turbine. The fuel is pumped at 280 lb pressure through two Griscom-Russell fin-type fuel-oil heaters which can be operated in battery or singularly. The temperature is controlled by a Foster regulator at 230 F. After leaving the heaters, the fuel oil is pumped through a Bassler fuel-oil meter which corrects for temperatures to 60 F and records in gallons the fuel going to the Woolley burners. One pair of Coen suction strainers and a pair of Coen discharge strainers are in the fuel-oil line to prevent any sludge from interfering with the burners.



Elevation of part of boiler-room piping

SIZE GRADING
Applied to Terminal Velocity Of Fly Ash and Other Dusts

By HUDSON H. BUBAR

The author discusses the fallacy of attempting to determine particle size of sub-screen dust through ascertaining the terminal velocity by elutriation and urges instead that results be expressed in terminal velocity rather than particle size—a practice followed in Great Britain.

IT HAS been customary to represent the terminal velocity of fly-ash particles by their size, based on an average density for the entire sample. This is erroneous.

There is a wide variation in the chemical components of fly ash. Also, dependent upon location, there is a wide variation in weight. In some cases this weight runs as low as 18 lb per cu ft; in other cases it has been found to run as high as 105 lb per cu ft. The variation is further influenced by carbon content and shape.

The most common means of attempted determination of particle size of sub-screen dusts has been by air elutriation, which is based on rate of settling. A sample is selected, an average density established, fixed velocities set in the elutriator and the sample run. From the results obtained a chart is made on which, based on the average density, fixed percentages of fly ash are stated within a certain micron diameter ranged generally as follows: 0–5, 5–10, 10–20 and 20–40 microns.

This chart is then applied to embrace all fly-ash conditions, irrespective of location, density variation, variation in carbon content or in particle structure. However, such charts are not accurate. In fact, one may safely state that, on the average, fly-ash particle size cannot be determined by air elutriation within 50 per cent accuracy.

The average fly-ash sample, precipitated at any fixed velocity and stated within certain limits, say 10 to 20 micron diameters, will often run more than 50 per cent outside those limits, with a minimum diameter as low as two microns and a maximum diameter of 44 microns. Furthermore, where the coarser particles have not been screened out before elutriation, the maximum diameter of some will be above 60 microns.

Fly ash is a heterogeneous dust. Its composition is generally stated as being ash and carbon. The real composition is, however, much more complex and, in most cases, consists of the following elements in varying percentages and in varying combinations:

Ash	Silica Alumina Iron Titanium Lime Magnesia Potassium Sulphur	Varying from 25 to 80 per cent of the total
	Carbon	Varying from 20 to 75 per cent of the total

The ash combinations may generally be stated as being SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O and SO_3.

A wide percentage variation of each of these is found, according to the seam from which the coal comes. Dependent upon furnace conditions and original percentages of certain of these elements, further combinations may be formed such as aluminum silicates, calcium aluminates, etc. The carbon may be in the form of unburned coal particles, solid spheres, hollow spheres, broken shell-like particles, extremely porous coke-like particles or soot.

The specific gravity of fly-ash particles will range from two to as high as seven. But the range in density cannot be assumed as limiting the terminal velocity range, as many of the heavier elements remain in the fly ash as solid particles, either of crystalline or spherical formation, whereas many of the carbon particles are either hollow spheres, broken shells or have coke-like formation, all tending to increase the air resistance of the particle to a point where the terminal velocity is greatly reduced. This is shown in the following tabulation, in which have been selected three of the more common elements found in fly ash.

MEAN TERMINAL VELOCITY IN MILLIMETERS PER SECOND

Micron Diameter	Fe_2O_3	SiO_2	Average Carbon Particle
10	25	$4^1/_2$	2
20	100	18	
44	506	91	49

Here we have a terminal velocity ratio of approximately one to twelve, wherein particles of fly ash of the same micron diameter, but of different density and shape, will have a settling range of extreme variance. Where the light fluffy particle will carry twelve miles the heavy particle will carry only one mile.

In setting up an elutriator for the 20–44 micron diameter in the first stage, the 10–20 in the second stage and the 0–10 in the third stage, the velocities would be set for the approximate lower size in each case, as follows:

1st stage, 20 micron diameter
2nd stage, 10 micron diameter
3rd stage, 1 micron diameter

The terminal velocity would then have to be established at an intermediate point of density, say, in this case for the silica particles of 20-micron diameter at about 60 mm per sec. On this basis most of the iron oxides and a certain percentage of the silica would be well below 20 microns in diameter whereas most of the carbon particles would be well above 44 microns, probably averaging above 60 microns. When assuming only 30 per cent of carbon in the ash the possible percentage retained within the limits of 20–44 microns might approach 50 per cent. However, when dealing with a 50, 60 or 70 per cent carbon content in the fly ash the results would be much worse.

The foregoing demonstrates the fallacy of stating percentages of particle size by air elutriation. Furthermore, it illustrates the fallacy of basing guarantees of fractional efficiency on any such determinations as are not possible of definite proof.

Even when dealing with homogeneous dusts of like density and particle formation, the elutriator cannot be depended upon to give accurate size results as is shown by Roller[1] in his experiments with portland cement and chrome-yellow pigment. Analyzing his experiments we have the following approximation of size accuracy within the limits set.

HOMOGENEOUS DUSTS OF LIKE CHARACTER AND DENSITY SUCH AS PORTLAND CEMENT

Micron Diameter	Per Cent Within Range	Per Cent Under Range	Per Cent Above Range	Particle Diameter—Above and Below Range Minimum	Maximum
0– 5	99.5	...	0.5	...	10 mu
5–10	73.0	11.0	16.0	2 mu	16 mu
10–20	77.0	18.0	5.0	5 mu	32 mu
20–44	75.0	18.0	7.0	12 mu	70 mu

In this table it will be noted that on a micron range of from 5 to 10 diameters an accuracy of 73 per cent is obtained, whereas on a variation of 10 micron diameters (from 10 to 20) 77 per cent is within range. On the 20–44, with a diameter variation of 24, 75 per cent is within range and the largest particles were 70 microns.

All this points to the fact that the fault does not lie with the elutriator but almost entirely with the interpretation of the results shown by the elutriator.

In the size analysis of dust particles the screen has been depended upon to give the size range above 44 micron diameters or 325 mesh. On screens finer than 325 mesh the percentage of accuracy dropped off rapidly and because of this the elutriator has been used in attempting to carry the size grading down through the lower micron diameter range.

However, size grading and terminal velocity have nothing in common except where the dust is of uniform density and particle structure and even then only a rough approximation is obtainable. Therefore, the error lies in the attempt to apply terminal velocity to the size grading of heterogeneous dusts, in particular fly ash.

It has been common procedure to state all fly-ash particles of equal micron diameter as having the same settling rate. This is extremely misleading. Under actual conditions a 100-micron diameter particle of carbon as commonly found in fly ash will travel farther than will a 20-micron particle of iron oxide or silica.

Elutriator operation is based on terminal velocity. Why not apply the principle of elutriation to the entire sample and state it in terminal velocity, as is required in Great Britain?

After all, the terminal velocity of dust particles is more important than is the particle size, in the consideration of a dust nuisance. By the terminal velocity the rate of fall of the dust particle is directly established much more accurately and with much less work than by the present roundabout method of trying to determine particle size of heterogeneous dusts. After particle size has been determined it must be again converted to terminal velocity to get the true conditions. By the terminal velocity are also established the approximate length of time the finer particles remain in suspension and the distance traveled at stated wind velocities and elevation of point of discharge, before final settlement. From this can also be approximated the blanketing effect on sunlight. In fact, if total consideration of the test or problem were based on terminal velocity only, a much clearer and more accurate picture would be had.

The question raised is not new; among technicians it has been recognized for some time past. It is for the reasons stated that Great Britain requires that the results be expressed in terminal velocity and not by particle size.

Our testing laboratories also recognize the fault, yet continue to express by size only because that has previously been the method used—right or wrong. The U. S. Bureau of Mines recognizes the difficulties and recommends elutriation for the determination of terminal velocity as being the most practical.

It is generally agreed that it is almost impossible to determine an accurate size analysis of sub-screen dusts. Theoretically, it is possible to disperse a sample of dust on a microscopic slide and proceed to measure the particle size. In practice, however, such procedure is not only extremely difficult, but also very costly. Furthermore, the attempt to cut from the main sample a sample sufficiently small for dispersement on the slide, with assurance that it is truly representative, is extremely difficult, if not impossible. To prove this statement, all that is necessary is to select any dust sample and from it cut, as carefully as possible, four different slide samples. When placed under a microscope these samples will show a conflicting size count over a considerable range.

As has been previously asked, just what are the advantages of this method of determination and expression on particle size of subscreen dusts? Certainly there is no accuracy of determination. Also, the indications as to length of travel of the dust particle are very misleading, and, because of this, the expressed extent of the dust nuisance is misleading. A dust nuisance may be classified in three ways as follows:

First, by the contaminating effects of the dust, based directly on the amount falling in any fixed area. This is governed by the terminal velocity.

Second, by either the toxic or corrosive effect of the dust. This is also governed by the terminal velocity as controlling settling in any given area.

Third, by obstruction of sunlight. This is also governed by the terminal velocity for the same reason.

Then, why not directly determine and express by terminal velocity instead of attempting to determine the particle size and from this set up a fictitious picture of terminal velocity?

[1] Technical Paper 490, U. S. Bureau of Mines.

Superheaters and Economizers

Their Design and Safe Operation

Abstract of a paper presented at the Thirteenth General Meeting of the National Board of Boiler and Pressure Vessel Inspectors in which the author reviews the conditions imposed by high-pressure, high-temperature operation and outlines how these are being met by the design and handling of such equipment for modern installations.

By H. B. OATLEY, VICE PRES.
The Superheater Company

ALTHOUGH the use of economizers and superheaters, as component parts of a steam generating unit, dates back a number of years, it is in recent years that they have assumed greater importance. In fact, in the modern large high-temperature, high-pressure unit the superheater may be considered as the most important single component, and it is necessary that its designer have expert knowledge of the design and performance of every part of the steam generating unit which it serves.

Economizers

Even though the economizer has had to take a deferred ranking as compared to the superheater, its design, location and proportioning can contribute much to the successful operation of the steam generating unit. There are, of course, certain economic factors to be taken into consideration, as the economizer must compete against both boiler evaporating surface and multistage feedwater heating by bleeding steam from various stages of the turbine for this purpose.

In many smaller plants it is common to install an economizer, in connection with existing boilers, in the duct work between the boilers and the stack. Sometimes a separate economizer is employed for each boiler and in other cases where a number of small boilers are involved, a single economizer serves several boilers. Generally speaking, each ten-degree rise in feedwater temperature thus obtained from otherwise wasted heat represents a reduction of approximately one per cent in fuel. The value of the fuel saving can therefore be balanced against the cost of the economizer installation in determining its economic justification for any given installation.

In modern high-capacity, high-pressure installations, economizer surface, within certain limits, is less expensive than boiler evaporative surface for the same heat recovery. Furthermore, the space occupied by the economizer will be more favorable and the operating performance at least as good or better than a comparable bank of steam generating tubes.

Inasmuch as chemicals for feedwater treatment are frequently introduced ahead of the economizer it is desirable that any possibilities of evaporating water in the economizer be avoided, in order that there be no precipitation and deposits in the economizer tubes. However, due to uncontrollable conditions it is sometimes impossible entirely to prevent some deposits within the tubes and an accessible design is used.[1]

Superheaters

Whereas the older superheaters absorbed less than 5 per cent of the total heat of the entire unit, the modern superheater will absorb more than 25 per cent of the heat of the fuel. The materials have changed from low-carbon steel tubes, for low degrees of superheat, to expensive chrome-nickel-molybdenum alloy steels in modern high-temperature units in which superheater weights of 350 tons or more are not uncommon for high-capacity units.

The most serious operating condition which the superheater must withstand is that obtaining during the starting-up period, especially where it is exposed or near to the furnace. In the past it was common to flood superheaters during starting up.

While this may have been satisfactory with the superheater located in a zone of relatively low gas temperature, as above the tube bank in a sectional-header or box-header boiler where the gas seldom exceeded 1000 F during this period, it has not worked out well with superheaters located in the high-temperature zone. This is because the boiler water generally contains some dissolved salts which upon evaporation will cause deposits within the superheater. A more satisfactory procedure is to provide for the circulation of steam through the superheater elements during the period of starting up the unit.

Adequate steam velocity and pressure drop is essential to protect the superheater during normal operation. In this connection, the superheater designer is sometimes placed at a disadvantage because the consulting engineer or the purchaser specifies an abnormally low pressure

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[1] The author showed two designs of Elesco economizers in general use—one, Type *A*, an accessible design employing bends on one end and bifurcated flanged connections on the other for use with unfavorable feedwater conditions; and the other, Type *C*, employing continuous loops and suitable for use with good feedwater and small makeup. Each type employs moderately small tubes with welded-on fins both top and bottom, providing streamline flow of the gases, minimum resistance and maximum surface for heat recovery.

drop through the superheater. Often, the pressure drop through the piping beyond the superheater is greater than that allowed through the superheater, yet the piping system requires no protection against overheating. A fair allowance for superheater pressure drop would be 5 per cent.

Fortunately, low-pressure installations generally employ relatively low steam temperature while the high-temperature installations are accompanied by high pressure where greater pressure drop is permissible. The combination of relatively low pressure and high temperature presents a problem in which an adequate steam velocity and pressure drop will greatly simplify the design of the superheater.

Moisture Carryover

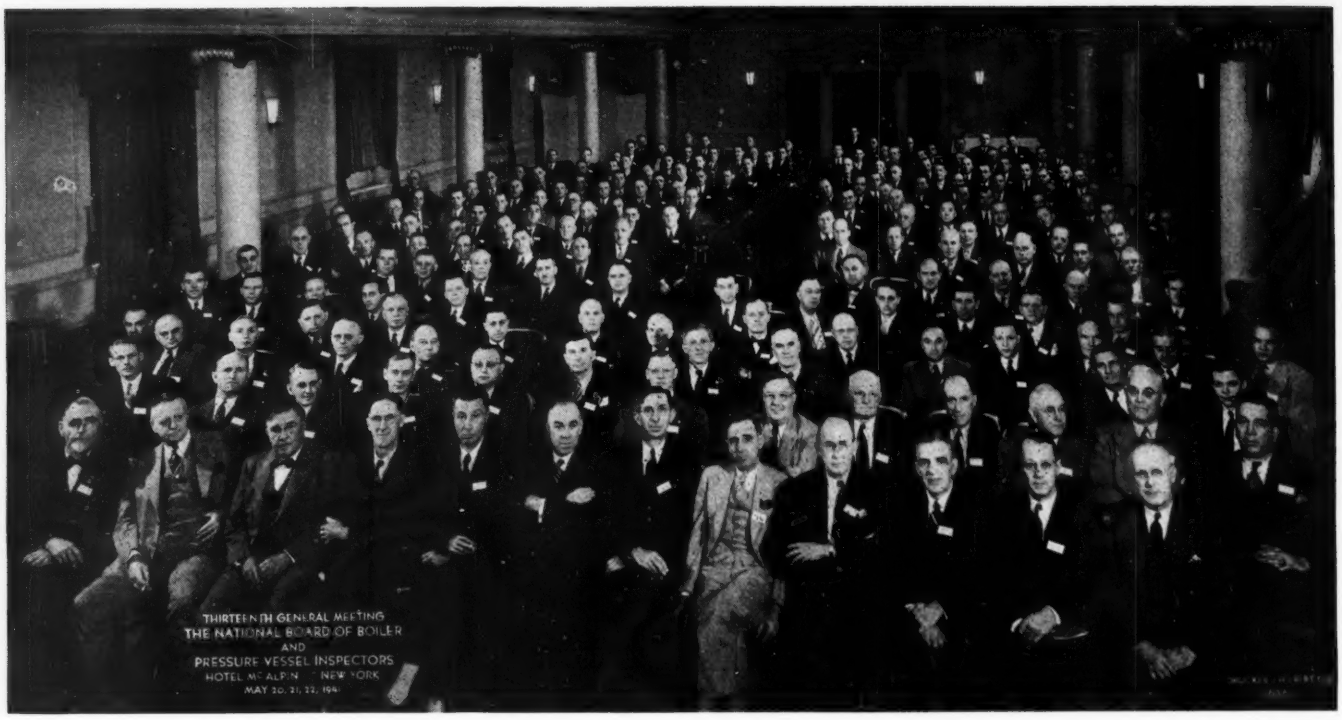
Where moisture carryover is small and the steam velocity high, any solids carried over are likely to pass through the superheater elements without depositing on the internal surfaces. However, if an appreciable amount of moisture is present, the solids are precipitated out upon evaporation of the moisture and form deposits on the inside of the superheater tubes. Such a condition is detrimental and has been the cause of superheater failures. Where such deposits are soluble in water the tubes can usually be cleaned satisfactorily by washing with water. Sometimes with harder scale turbining will effectively remove the deposits.

Oxygen in steam coming from the boiler drum does not seem to have any detrimental effect on superheater tubes. However, when it is accompanied by excessive moisture, whether in a continuous amount or intermittently, the result is usually quite detrimental. It would appear that a continuous moisture carryover of about 2 or 3 per cent, together with excessive oxygen content, causes a slow but certain oxidation of the inside of the saturated steam portion of the tubing. This is evidenced by pitting and finally by failure. When the oxygen is accompanied by occasional moisture carryover, which may reach a large percentage, the action on the inside of the tubes is more severe. In this case more rapid oxidation of the inside of the tubing and more frequent failure seems to result. This type of failure is usually accompanied by the formation of a deposit of magnetic oxide of iron.

Causes of Overheating

The cause of overheating of superheater tubes is essentially the same as overheating any other tube in a steam generating unit—namely, concentration of heat on the outside or scale formation on the inside. The former may be due to improper burner adjustment, improper location of baffles, or ash accumulation over one section of the superheater, thereby causing increased gas flow over other sections or the presence of abnormally unequal gas passages through some of the superheater elements.

In conclusion, it may be stated that the designer is ever on the alert for ways and means of meeting the more exacting performance requirements and the more severe operating conditions which come into being as time goes on. This means the perfect coordination of manufacturing, engineering and materials.



Boiler Inspectors Meet at New York

APPROXIMATELY thirty addresses and papers constituted the three-day program at the Thirteenth General Meeting of the National Board of Boiler and Pressure Vessel Inspectors at the Hotel McAlpin, New York, May 20 to 22, with an attendance of over 350. Following a number of general papers, sessions were devoted specifically to boilers, to piping and to process vessels.

E. B. Ricketts, Mechanical Engineer of the Consolidated Edison Company of New York, discussed developments in high-pressure piping in its relation to the revised edition of the Piping Pressure Code which is now about ready. Important changes in the Code cover extension of maximum steam temperatures to 1000 F, a revision of the allowable stress values, completely rewritten chapters on welding, flexibility and hangers.

With reference to agreement with the A.S.M.E. Boiler Code, Mr. Ricketts pointed out that the latter claims jurisdiction up to the second stop valve; but this, he showed by several typical diagrams, includes most of the boiler room piping in some of the modern stations. Where a single boiler and turbine are concerned it takes up to the turbine stop valve. As a result one must design partly in accordance with the Boiler Code and partly in accordance with the Pressure Piping Code. He therefore suggested that the Boiler Code confine itself to the equipment furnished only by the boiler manufacturer.

In discussing this paper, **J. F. Scott,** Chief of the License and Inspection Bureau for New Jersey, expressed the opinion that Mr. Ricketts was mistaken in his conception of the coverage of the Boiler Code. This, he explained, provides for two shutoff valves between the boiler and the main steam line, which valves should be as close as possible to the boiler; but that the Boiler Code Committee had always endeavored to avoid jurisdiction over the piping system, which is extensive in a modern boiler plant.

E. A. Kerbey, of the Midwest Piping & Supply Company, in a paper on "Design and Fabrication of Piping Systems by Welding" showed numerous shop views of welded fitting and piping sections and explained that welding in such cases had not only reduced weight but had lowered overall costs by eliminating loss in castings. Moreover, shop devices rotate the work so that welding operations can be carried on in the "down" position and thus assure a better job. He mentioned the practice of cutting piping members short one-half the calculated expansion so that there will not be distortion under operating temperatures.

P. R. Cassidy, of Babcock & Wilcox Company, in a paper on "Developments in High-Pressure Boilers," discussed the 1940 revision of the A.S.M.E. Boiler Code with particular reference to tube thickness and the fusion welding of butt ends of tubes. The rules for fusion welding have been simplified and the Code now permits steel of 85,000 to 102,000 lb tensile strength. He emphasized the necessity of designing to avoid stress concentration and the importance of stress analysis rather than employing average figures for stress.

The Code now includes specifications for about sixty steels many of which are alloy steels. While very little alloy steel is being used in boiler plate considerable is going into tubes and superheaters. High chromium content does not mean increased strength but rather increased resistance to oxidation; hence, its adaptability to high temperatures. Although carbon-molybdenum steel possesses no particular advantage over carbon steels as regards oxidation, it has much better creep characteristics.

The second part of Mr. Cassidy's paper was devoted to illustrations and descriptions of certain high-pressure boiler designs.

Putting Boilers in Service

J. H. Harlow, of the Philadelphia Electric Company, described in detail the procedure adopted by that company in putting in service the large high-pressure steam-generating units at Chester Station. All hydrostatic tests were made with distilled water taken from low-pressure boilers in the station and having a pH of over 10, in order to avoid corrosion. The units were heated initially by 250-lb steam from the other boilers and they were brought up to full pressure on the auxiliary oil burners. Permanent thermocouples, connected to the necessary instruments, were installed not only for use in initially putting the units in service, but also for use every time a unit is taken off and put back on the line, in order that temperatures in various locations may be observed.

Noting the difference between the operation of high-pressure, high-temperature units and low-pressure boilers, Mr. Harlow reviewed the training of operating personnel for this service. This includes aptitude tests, followed by some weeks of study of the new equipment and initial operation under the guidance of the manufacturer's representatives. Some of the older men find it difficult to adjust themselves to the new conditions, but as such situations arise they must be handled with due regard to seniority.

Rolling Boiler Tubes

The elongation method of controlling the rolling of boiler tubes, as employed by The Detroit Edison Company, was described by **E. T. Cope.** This employs a gage attached to the tube a few inches beyond the plate and having a stem resting on the plate, the elongation due to rolling being indicated by the deflection of the gage needle. Experience has shown that there is a definite relation between the deflection of the needle and the maximum strength of the joint, and in high-pressure boilers an exact knowledge of the joint strength is necessary. Of more than 2000 tubes rolled under such control only 4 per cent showed any evidence of leakage.

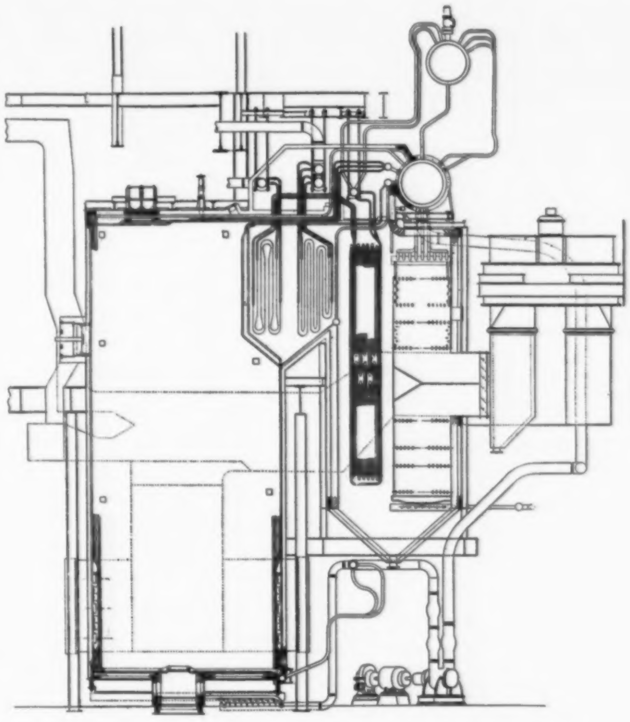
The speaker showed motion pictures of such rolling operations in the laboratory under conditions simulating those in the field. It was observed that the needle first oscillates as the rolling tool is inserted, then comes to rest as firm contact of the tube and sheet is made, after which the needle begins to deflect as the metal is elongated.

The speaker pointed out that over-rolling not only punishes the metal but actually decreases the strength of the joint; that lesser elongation is necessary with small tubes, greater tube-sheet thickness increases the strength of joint and that the sequence of rolling is important in order to avoid bowed tubes. He also questioned the advisability of flare of the tube ends and was of the opinion that grooves were sufficient to provide the necessary holding power. In this connection, tests had shown the double V-groove most effective.

Forced-Circulation Unit

Forced circulation, with particular reference to the 650,000-lb per hr, 1825-lb pressure, 960-F unit now under construction for the Somerset Station of the Montaup Electric Company was covered in a talk by **A. C. Weigel,** Vice President of Combustion Engineering Company, Inc.

The speaker pointed out the essential differences between this design and a natural-circulation boiler as involving the introduction of circulating pumps to augment the thermal circulation, the employment of adjustable nozzles in the lower header system to control the circulation to each of the circuits and the use of small diameter tubes which provide the desired turbulence. These pumps, of which there are three (including one spare) operate at a differential head of about 40 lb and handle a quantity of water several times the steam output, thus insuring positive circulation and fully wetted surfaces at all times independent of the load on the unit. Flexibility in the arrangement of heating surfaces to meet space requirements is possible with this type.



Sectional elevation of the Somerset forced-circulation unit

Included in the unit are a convection type superheater, reheater, economizers and regenerative type air preheater. It will be tangentially fired with pulverized coal and have a continuous slagging-bottom furnace. All tubes will be welded to the drums and headers.

Prevention of Furnace Explosions

R. M. Hardgrove of Babcock & Wilcox Company, in a paper on "Prevention of Explosions in Large and Small Boiler Furnaces," analyzed statistically a list of 139 furnace explosions, furnished by the Associated Factory Mutual Fire Insurance Company together with a list of 59 explosions compiled from the records of his own company. The two lists duplicated each other only to the extent of five explosions in the pulverized coal group, one in the oil group and one in the gas group. These records, while not complete, are nevertheless indicative.

Fig. 1 shows the distribution of these explosions by years from 1926 to date. The fact that the majority occurred during the last five years is not indicative of greater carelessness, but is attributable to the more widespread use of fuels burned in suspension. The damage claims shown are only those reported in the insurance list as such figures were not available in the

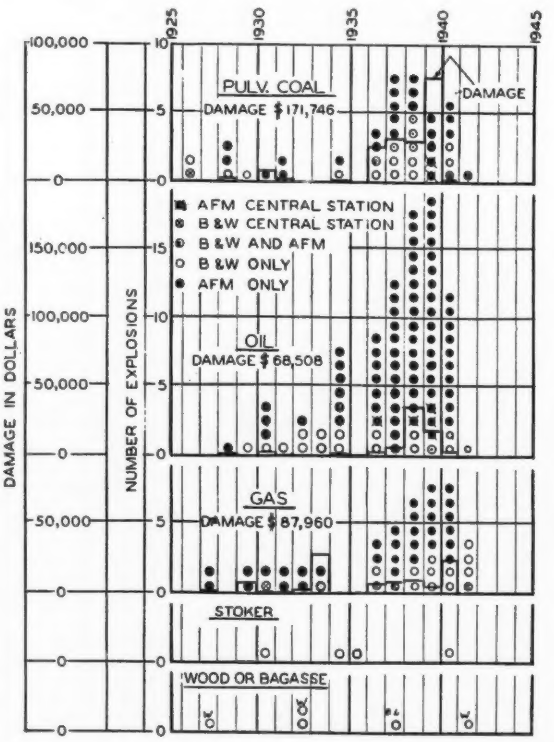


Fig. 1—Distribution of furnace explosions by years

other list. The totals do not necessarily give a true relative proportion as the pulverized coal group includes one item of $65,000 which disproportionately penalizes that group.

There are four explosions for stokers and fuel beds, and five for wood, bagasse and black liquor in the B&W list, and, no doubt, a number in the insurance company files which were not reported in the list furnished. The number of explosions shown in Fig. 1 does not indicate the relative hazards of the three fuels as they are not compared with the number of furnaces operating on each fuel during a given year.

It is significant that comparatively few of these explosions occurred in central stations. These are marked.

Based on a limited survey, 71 per cent of the pulverized coal, 75 per cent of the oil and 50 per cent of the gas explosions occurred during the first year of operation of the unit. When a plant is first started up the operators are unaccustomed to the equipment and often are not familiar with the possible hazards.

In Fig. 2 the number of explosions has been plotted for each fuel from 1936 through 1940 and compared with the number of new boilers above 200 lb pressure

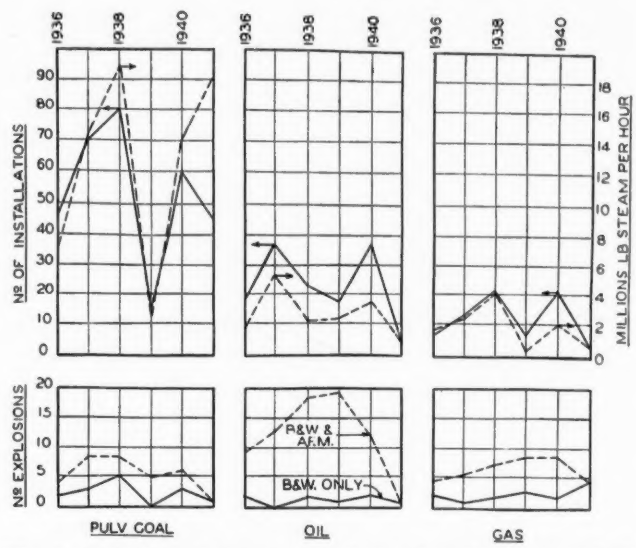


Fig. 2—Relation between number of explosions and the number of new units installed

in each group from a tabulation of installations published in *Power*. It will be noted that, although the cumulative number of furnaces in operation is increasing each year, the number of explosions is not: It is apparent that the ratios of explosions to new installations for oil and gas are about equal and about $4^1/_2$ times the ratio for pulverized coal. Gas is very explosive but maintains its ignition easily and if rules are obeyed can be handled without trouble; oil is less explosive but ignition is not as easy as with gas; while pulverized coal is the least explosive but the most difficult to handle.

Selection of the eight major causes of explosions with pulverized coal, oil and gas, which were responsible for over 70 per cent of the total, show the following:

DURING LIGHTING			
Poor lighting	19	explosions	(10%)
Lighting without purging	19	"	(10%)
Inadequate torch or spark	20	"	(10.5%)
DURING OPERATION			
Ignition lost, fuel not cut out	24	"	(12.5%)
Poor burners, giving unburned fuel	20	"	(10.5%)
Air reduced and restored	17	"	(8.9%)
AFTER SHUTDOWN			
Gas from torch or unburned fuel	9	"	(4.2%)
Blowing soot	8	"	(4.7%)

The majority of these explosions could probably have been prevented by the following precautions:

DURING LIGHTING

(*a*) Training operators to:
1. Obtain better lighting conditions such as the proper air velocity and ample quantity of fuel
2. Purge the furnace properly
3. Always use a torch in relighting
4. Maintain an ample torch
5. Inspect and maintain the spark used for ignition of oil or gas fuel

(*b*) Providing more reliable burning and lighting equipment

(*c*) So interlocking the equipment that it must be started in the proper sequence, such as: induced-draft fan, forced-draft fan, ignition torch and fuel

(*d*) Automatically insuring adequate purging by use of a purge meter which requires a specified air flow through the furnace for a specified time interval before the fuel can be started

(*e*) Automatically limiting the length of the ignition period

(*f*) Providing three simultaneously operated valves, two shutoff and an intermediate vent valve, on all gas-fired furnaces. Lever handles on the cocks to individual burners should be installed so that they are all vertical when open and horizontal when closed to eliminate the possibility of misunderstanding

DURING OPERATION

(*a*) Training operator to:
  1. Keep the air and fuel ratio within the proper limits
  2. Cut out the fuel when ignition is lost
  3. Light up additional burners properly
  4. Cut off the ignition torch during operation
  5. Blow soot only at medium or high ratings
  6. Maintain gas valves tight
  7. Operate at rates sufficient to maintain stable ignition

(*b*) Providing flame failure devices to cut off the fuel automatically on flame failure or to sound a warning signal

(*c*) Providing better combustion control to keep the fuel-air ratio within proper limits and prevent the damper positions from changing in case of failure in the automatic control system

(*d*) Interlocking the fans and fuel, a typical arrangement being:
  1. If the induced-draft fan fails it will trip out the forced-draft fan
  2. If the forced-draft fan fails it will trip out the fuel

  These interlocks are quite dependable where the fans are driven by motors, and are generally used on pulverized coal, oil and gas units. Where turbine-driven fans are used, the interlock is not quite so simple, although good reliability has been obtained by using lubricating oil pressure or steam pressure in the valve chest of the turbine. Interlocks using drafts or pressure are unreliable and even an air-flow meter may cause unnecessary trip-outs, as momentary swings sometimes occur which do not cause actual loss of ignition

(*e*) Providing shutoff valves to cut off the fuel on low oil or gas pressure. This feature is quite successful with gas, but does not take care of water in the oil. No satisfactory indicator for failure of pulverized coal supply has been developed

(*f*) Not using continuous pilot or torches

AFTER SHUTDOWN

(*a*) Training operators not to:
  1. Blow soot with unit shut down
  2. Run the pulverizer for test with burner lines open
  3. Allow torches to continue in the furnace after shutdown
  4. Permit gas valves to be accidentally knocked open
  5. Allow leaky valves to accumulate unburned fuel in the furnace

Mr. Hardgrove then described and discussed a number of flame-failure indicators of various types, and concluded his paper with detailed instructions for safe lighting procedure. He observed that while furnace walls cannot be constructed strong enough to withstand any possible explosion pressure, they can be made strong enough to withstand minor puffs, and the principal boiler manufacturers now design to withstand a furnace pressure of 36 lb per sq ft.

Exhibits

In connection with the meeting there was an exhibit by the insurance companies and by certain boiler manufacturers. In the latter a recently completed scale model of a Combustion Engineering Company two-drum VU type steam generator attracted much attention. A photograph of this model is shown on the cover of this issue. Constructed of aluminum, by E. C. Keithley, it represents in every detail the actual unit.

Fuel Consumption by Industry

The accompanying charts have just been issued by the Bureau of the Census showing the quantities of different fuels consumed by manufacturing establishments in the United States during 1939; also the geographical utilization of the various fuels. Comparison is made with similar census data compiled at ten-year intervals from 1909 to 1939.

Figures collected showed a material reduction in the consumption of coal and coke, a slight increase in the consumption of fuel oil and a large increase in the use of gas during 1939 as compared with 1929, but decreases in all four fuels from the figures of 1937. The 1939 consumption of bituminous coal and anthracite combined totaled 142,787,289 short tons, but the tonnage of anthracite burned in manufacturing plants has shown a continuous decrease since 1919 at which time it was 13,735,918 short tons compared with 5,015,857 tons in 1939.

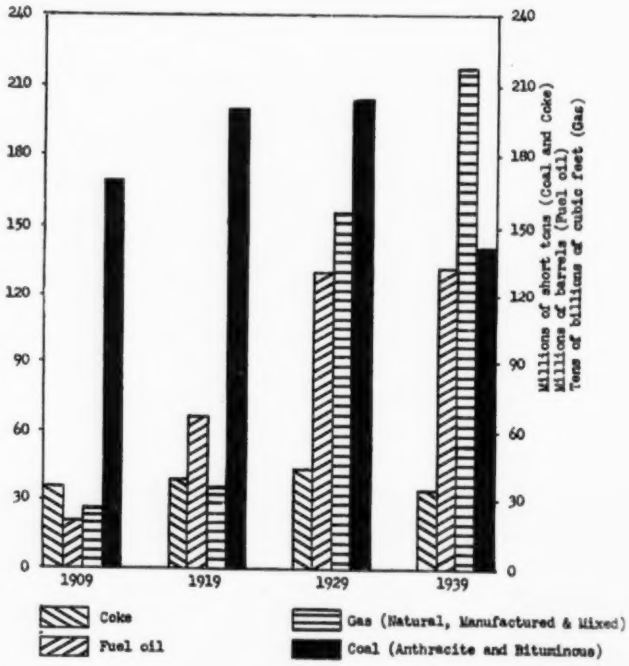


Fig. 1—Fuel consumption by manufacturing plants for census years 1909 to 1939

The heaviest users of bituminous coal, among manufacturing industries, were coal and petroleum products, followed in order by iron and steel, stone, clay and glass products, food products, chemicals, paper, textiles, automobiles, machinery and nonferrous metal products. As would be expected, the iron and steel industry was by far the greatest user of coke, accounting for nearly 95 per cent of the total. Petroleum products led in the use of oil with the iron and steel products a close second and the chemical industry third. Also the iron and steel industry was the largest consumer of manufactured gas and the chemical industry of natural gas.

Inasmuch as this was a Census of Manufacturers no figures were included on the fuel consumption by utilities. However, in another earlier report the Federal Power Commission summarized the fuel consumption by electric utilities in 1939 as follows: bituminous coal 42,441,-

038 tons, anthracite 2,243,984 tons, lignite 1,538,174 tons, fuel oil 17,423,456 bbl, and 191,130,940 M cu ft of gas.

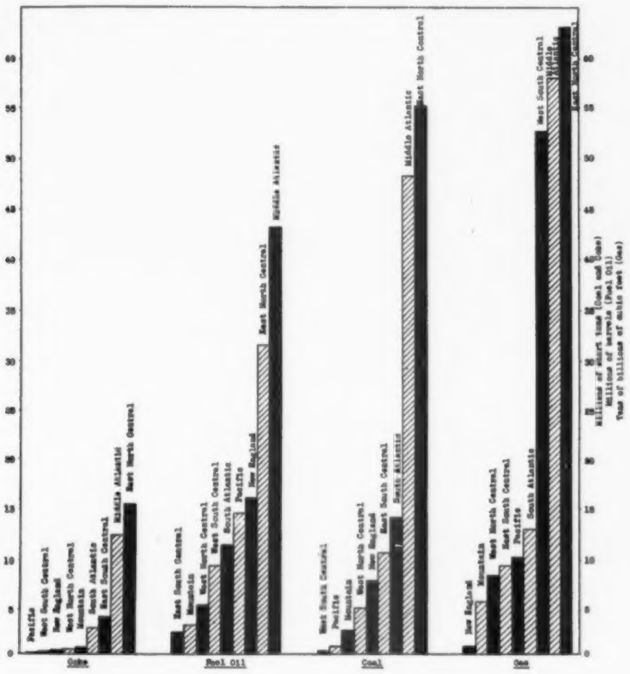


Fig. 2—Fuel consumption by manufacturing plants for 1939 according to geographic diivsions

Plan of Smoke Abatement Suggested for Pittsburgh

At an open hearing of the Pittsburgh Smoke Commission on May 13 the Western Pennsylvania Coal Operators Association presented a suggested plan to reduce air pollution in Greater Pittsburgh. This plan was based on the idea that it would be inadvisable to attempt to force extremes until the machinery and the human nature involved in a program of this type are ready for complete solutions, although it should not wait for the ideal solution before doing something.

To this end it was suggested that conflicting interests could be largely reconciled and hardships avoided by scheduling the program in three steps as follows:

1. The initial stage to be devoted to correcting the bigger sources of smoke, particularly flagrant violators.
2. An intermediate stage devoted to further organization and development.
3. A final stage representing the development, enactment and application of a permanent ordinance based on experience attained in the first two stages.

It was pointed out that during 1940 commercial and industrial concerns in the city of Pittsburgh burned over $2^1/_4$ million tons of high volatile coal for heating and steam-power purposes and that domestic consumers used over a million tons, whereas in the county as a whole these figures were nearly $4^1/_2$ and 2 million tons, respectively.

Of these tonnages that which is employed for domestic purposes is probably burned in a manner that produces appreciable smoke. A considerable portion of the commercial tonnage produces smoke due to faulty operation or obsolete equipment. The first stage of the recommendations would be directed at correcting smoke produced by the commercial tonnage; whereas enforcement of regulations with reference to domestic users would be deferred until improved stoves were available. Researches on such stoves are now being made at Battelle Memorial Institute, the University of Illinois and Pennsylvania State College. This solution is believed preferable to forcing such users to purchase higher priced smokeless fuels, such as is being done in some other localities.

With reference to so-called smokeless fuels, the report points out that anthracite costs $12 to $12.50 per ton in Pittsburgh; gas and oil can be regarded as luxury fuels and there is some question as to the availability of the former over a long period; semi-bituminous coal has less volatile but its use would involve some changes in the burning equipment and it is difficult to obtain in domestic sizes; coke requires a different operating technique and its availability is to some extent dependent upon operations in the steel industry; and the present supply of processed coal is inadequate. Finally, it is pointed out that the consumption of high volatile coal in the Pittsburgh area accounts for the employment of at least 2000 miners.

Regulation of Smoke Through Improved Equipment

Where industry has tried to eliminate smoke in its combustion operations, it has achieved this objective through improvement of combustion methods rather than through a change to more expensive fuels, and it has accomplished this often with large savings. As against the use of smokeless fuels, the use of a stoker is more economical, particularly for the larger consumers, as the stoker, while imposing an initial investment, involves no permanent increase in fuel cost. Actually, the stoker provides savings for large fuel users which more than pay for the investment. Just where the line lies, beyond which a stoker is a profitable investment against hand firing, is difficult to state with complete assurance, but it has been demonstrated that all industrial and commercial users can justify the investment in terms of efficiency returns.

The report concludes with the statement that it is logical to assume that any ordinance adopted by bituminous-producing Pittsburgh which restricts the use of its own coal would likely be followed by other cities using this coal; whereas if the right solution to cleaning up the atmosphere around Pittsburgh is found other cities will emulate the example.

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